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OFFICE OF
COAL
RESEARCH &
TECHNOLOGY

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# Contents


2 **Preamble**

3 **Introduction**

3 Chairman's Report

5 Background

7 Coal Research Strategy

8 Research Priorities

9 **Research & Technology Programs**

9 A/CERRF-Funded Projects

34 Western Canadian Low-Sulphur Coal to Ontario Program

39 **Project Expenditures**

47 **Appendix**

47 A/CERRF-Funded Projects

54 Department-Funded Project

54 Western Canadian Low-Sulphur Coal to Ontario Program

# Preamble

The Alberta Office of Coal Research and Technology was established January 20, 1984, by Ministerial Order under the Department of Energy and Natural Resources Act.

The purpose of the Office is to co-ordinate the Alberta government funding needed to identify, investigate and develop coal-related technologies considered to be commercially important during the next decade. Its goals are:

- to minimize the environmental impact of coal production, transportation and use in Alberta and elsewhere;
- to enhance the competitiveness of Alberta coals in domestic and international markets; and
- to develop new uses for Alberta coals.

Appointed to the Office are J.K. Kleta as Chairman, and Garnet T. Page and Michael A. Ward as Members. T. David Brown represents Energy, Mines and Resources Canada as an observer and participates in project reviews.

Initial government funding for the Office was provided by the Alberta/Canada Energy Resources Research Fund (A/CERRF). Since it is expected that this fund will be fully depleted next year, it has been supplemented by funding from the Alberta Department of Energy.

# Introduction

## Chairman's Report

During 1990/91, the Alberta Office of Coal Research and Technology continued to support coal research and technology development primarily through the A/CERRF-funded Alberta Coal Research Program and the Western Canadian Low-Sulphur Coal to Ontario Program. Many projects in these programs were carried out and partly funded by the private sector. Others were funded entirely by the Office and carried out at universities and research institutions. One major project, the Alberta Coal Geology Program, which was formerly funded by the Alberta Department of Energy through the Office, is now funded through the Mineral Resources Division of the same department.

All these investigations were based on the 1983 Alberta Coal Research Strategy, which was revised in 1990 after consultation with the private sector and interested government agencies. This consultation led to research goals for the 1990s that will help develop coal-related technologies which are considered to be commercially important for the period 1995 to 2005. These goals are:

- to minimize the environmental impact of coal production, transportation and use in Alberta and elsewhere;
- to enhance the competitiveness of Alberta coals in domestic and international markets; and
- to develop new uses for Alberta coals.

These goals will allow the Office to continue to build on its past activities and experience, and will require an even greater emphasis on the environmental aspects of coal production and use than previously.

During 1990/91, projects funded by the Office helped several technologies to advance toward commercial applications. They are listed below.

**Environment-Related Technologies:**

- Low $NO_x/SO_x$ Burner Demonstration (also related to new uses for Alberta coals);
- IGCC Feasibility Study; and
- Advanced Coal Combustion Science (improved efficiency and reduced emissions of $NO_x$).

**Coal Quality-Related Technologies:**

- Coal/Oil Upgrading; and
- Coal/Oil Co-processing (also related to new uses for Alberta coals).

**Coal Transportation-Related Technologies:**

- Coal Slurry Pipelining (coal/oil or coal/water mixtures).

In addition to these projects, the Office continued to support coal characterization and coal geology studies. These activities are now being phased out. Budget constraints forced the University Grants Program to be terminated last year, and the Alberta Research Council core-funding for studies of coal utilization was concluded. From now on, research proposals received from universities and institutions must be considered within the overall context of the revised research strategy and current priorities. This means that all proposals must respond to the needs of industry and have industry support.

This past year, the Office continued to provide administrative support to the joint industry/government technical committees established previously. These committees provide a useful forum for expressing and acting upon mutual interests, and sharing research and development costs on projects aimed at solving operating problems. As programs near completion, the tasks of most technical committees also come to an end. Most committees will be phased out next year or replaced by new ones as the focus of research changes.

The coal gasification technical committee remains active, and a new committee was formed to examine options for carbon dioxide use or disposal. The $CO_2$ R&D Network (CORDNET), which was created this year, acts primarily as an information-sharing body, rather than a typical technical committee.

The Office continues to encourage collaboration among research and development organizations in Alberta, Canada, and several other countries. Currently, the Office is involved internationally in projects with Japan, the Federal Republic of Germany, and several European countries through the International Energy Agency.

During 1990/91, the Office received 18 requests for research funding, of which 10 were approved for Office contributions. In addition, funding support was continued for 16 projects approved previously. The total 1990/91 research funding contributions by the Office were $3.1 million, representing 37 per cent of total research expenditures for approved projects.

Day-to-day administration of Office projects is provided by staff in the Research and Technology Branch of Alberta Department of Energy, under the direction of D.E. Macdonald, Secretary to the Office. Additional assistance, co-operation and considerable support were received from the coal industry, research institutions and intergovernmental organizations.

The results of many investigations supported by the Office are available to industry and other interested parties through technology transfer publications. These are available from the Office or the Alberta Energy/Forestry, Lands and Wildlife information centres in Calgary and Edmonton.

J.K. Kleta
Chairman

# Background

Alberta's coal industry provided an important energy source during early development of the province. It continued to contribute significant economic activity until about 1950 when the coal market collapsed because large amounts of oil became available as a replacement fuel. In the mid-1960s, a resurgence occurred in the export market for metallurgical coal and in the provincial market for thermal coal. By 1974, annual production had risen to 9.5 million tonnes.

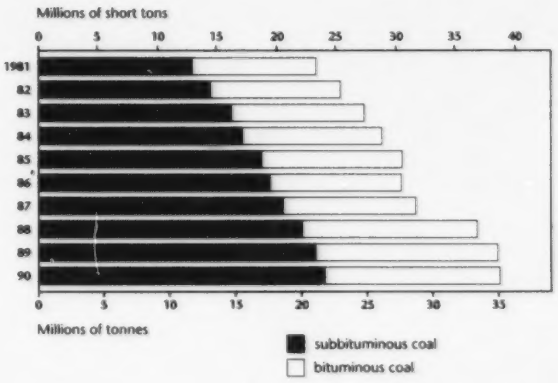
Alberta's raw coal production rose steadily after 1975, reaching 35 million tonnes in 1989. In 1990, raw coal production rose slightly to 35.2 million tonnes.

Today, Alberta is Canada's largest coal-producing and coal-consuming province. Its 12 major coal mines produce three types of coal for three different markets. Approximately two-thirds of total production is subbituminous coal produced from plains mines and used for power generation at mine-mouth electricity-generating stations.

High-quality, bituminous metallurgical coal is produced from three mountain coal mines for export to the steel industries in Japan, Korea and Brazil. Low-sulphur bituminous thermal coal is produced from two mines in the foothills region of Alberta for export to Ontario, Japan and Korea. Also, five small mines in the plains area of the province supply coal for the local market.

Although the international coal market is still in an oversupply situation, several thermal coal mines in the foothills region have been approved for development when export markets warrant. Income earned by Alberta's coal producers is derived from exports of bituminous coals, and from subbituminous coals used by Alberta utility companies to produce more than 91 per cent of Alberta's electricity. Approximately 2 400 people are directly employed by Alberta's coal producers.

**Raw Coal Production**




These statistics emphasize the importance and some of the benefits of Alberta's coal industry, but there are other advantages to having a healthy coal industry in the province. For example, coal mines provide a high economic and social return on the affected land. Also, the sale of coal to other countries improves Canada's trade balance, contributes to expansion of the transportation network, and fosters growth in the provincial construction industry during periods of expansion. Other direct benefits include financial contributions to all levels of government, and the purchase of goods and services within Alberta.

It is expected that Alberta's coal industry will continue to supply the low-sulphur fuel that makes electricity available to all Albertans at little economic or environmental cost. In addition, it will encourage the growth of secondary industries, provide a reliable and economic energy source for recovery of the province's heavy oils and bitumen, and make other significant contributions to the province's economic base.

To optimize these benefits, however, coal-exporting companies must continue to capitalize on the upturn in the Japanese economy and improvements in prices paid for Alberta coal. Although this situation is somewhat hampered by a rising Canadian dollar relative to several currencies, record deliveries of bituminous metallurgical and thermal coals were made in 1989. In 1990, overseas sales were down by nearly six per cent. Overall deliveries, however, declined only slightly (from 30.8 to 30.4 million tonnes) because sales of subbituminous coal for power generation in Alberta rose from 21.4 to 21.7 million tonnes.

Today's market conditions make it essential that Alberta coal producers use the most efficient and economical technologies available in coal exploration, production, preparation, upgrading, transportation and marketing. Increasingly, overseas customers are demanding coal and coal products that exhibit specific qualities and behaviour. This means that coal producers must know more about the combustion characteristics of their products. They must also be involved in the development of new technologies such as agglomeration, coal-water fuels, and other upgrading processes that will produce coal products tailored to market requirements.

The Alberta coal industry's response to these difficulties and challenges is expressed in the Alberta Coal Research Strategy, published in November 1983. This document was the result of extensive discussions among individual companies and the provincial government. In 1984, the Alberta Office of Coal Research and Technology was established. Subsequent industry proposals that were submitted to the Office resulted in research and development projects funded jointly with the Alberta government.

Other research projects funded by the Office have been carried out by the Alberta Research Council and the former Coal Mining Research Company.

Another important function provided by the Alberta Office of Coal Research and Technology is the co-ordination of coal research and development activities within Alberta, as well as between Alberta and national and international agencies.

This activity has led to better integration among the various coal research groups in Alberta. Also, it has resulted in a stronger focus on the needs of industry, and has produced international contacts and greater international co-operation.

The Office has directly influenced research and development activities within Alberta by funding projects jointly with the following: individual coal-producing companies or groups of companies, other government agencies, universities, private research organizations, consultants, utilities, equipment suppliers and agencies in other countries.

The Office is both influencing and benefitting from coal research and development elsewhere by participating on various national and international committees, including the International Energy Agency's Working Party for Fossil Fuels, and the Canada/Japan Coal Conversion Research and Development Committee.

# Coal Research Strategy

### Research Rationale

Consistent with the views of the Government of Alberta, the Alberta Office of Coal Research and Technology believes the private sector should take the lead in identifying and managing appropriate research and development programs, as well as implementing and commercializing the results. The role of the Office and other government agencies such as the Alberta Research Council, along with universities and research organizations, is to support the private sector as necessary to achieve the desired technical results most efficiently.

While there is a recognized need for longer-term research and development, as well as basic research to facilitate a better understanding of coal properties and uses, the critical time for commercial expansion and economic development of the province's coal resources will be from 1992 to 1998. During this time, growth in thermal coal use throughout the world is probable, but Alberta's share of the market will be influenced by increased competition from other coal exporters. The extent to which this expansion of thermal coal use can be realized, however, will depend on the prices of other energy supplies, such as natural gas and oil, and the relative social and environmental acceptance of coal versus other fuels or nuclear power.

Towards this end, in 1984 the Alberta Office of Coal Research and Technology identified initial funding through the Alberta/Canada Energy Resources Research Fund of approximately $20 million in support of research, development or demonstration projects. It was anticipated that similar funding would be forthcoming from the private sector. Thus far, contributions from industry have exceeded $35 million.

A portion of the funding is being used for longer-term or fundamental research directed toward innovative technologies related to production and use of Alberta coals.

Alberta must collaborate closely with research groups elsewhere to ensure that maximum benefit is derived from the total international coal research and development effort, and to define its intermediate- and long-term plans within this context.

In pursuing its objectives, the Alberta Office of Coal Research and Technology works closely with The Coal Association of Canada, the Alberta coal industry and coal research agencies to establish research and development priorities. In addition, the Office maintains contacts world-wide with researchers who are engaged in coal-related studies.

### Administrative Framework

The Alberta Office of Coal Research and Technology does not have in-house facilities to carry out research projects. Rather, its primary role is to provide funding for approved coal research projects. Therefore, procedures have been established to ensure sound project management and financial control of approved projects. For each project, specific agreements are signed that define the terms and conditions under which the project will be conducted and funded. These agreements also define the respective rights to new project technology ownership and use.

After proposals have received thorough consideration, those falling within the interests of the Office are discussed in detail with the applicant, and are often referred in confidence to one or more experts for detailed technical review.

An Alberta government interdepartmental group has been established to review and comment on the implications of the proposed research on their areas of responsibility. This group includes representatives from the Energy Resources Conservation Board and the departments of Forestry, Lands and Wildlife, Economic Development and Trade, Environment, and Community and Occupational Health.

Approval of research proposals by the Alberta Office of Coal Research and Technology takes into consideration the results of these reviews, relative funding contributions and the likelihood that proposed research will contribute to achieving the goals of the Alberta Coal Research Strategic Plan. Those projects funded by the Alberta/Canada Energy Resources Research Fund are submitted subsequently to the A/CERRF Committee for approval.

## Research Priorities

Since the Alberta Coal Research Strategy was prepared in 1983, several important events have occurred that could significantly affect Alberta coal producers, particularly those depending on export sales.

For example, Ontario Hydro is considering the use of more low-sulphur western Canadian coals to help meet provincial acid gas emission guidelines and establish a reliable domestic coal supply. This has resulted in a commitment by both industry and government to reduce the delivered cost of western Canadian coal in Ontario.

In Alberta, emphasis is being placed on expanding opportunities to use coal in place of natural gas to generate steam for enhanced oil recovery operations.

World-wide, the development of new coal-use technologies is generating demand for certain types of internationally traded thermal coals. Suppliers are now aware they should be providing thermal coals tailored to these new systems. Success in these markets will depend on having a better understanding of the performance characteristics of coal products under different operating conditions. Coal gasification developments are of particular interest to the Office and Alberta coal producers.

These changes have been influential in bringing about some modifications to the research priorities of the Alberta Office of Coal Research and Technology. Currently, those priorities are as follows:

- to develop and apply technologies that help expand opportunities to use coal in Alberta, particularly for producing and upgrading heavy oil and bitumen. Currently, several projects are under way to encourage the use of coal to displace natural gas for steam raising in enhanced heavy oil schemes;
- to develop and apply technologies that will have a significant effect on reducing the delivered cost of Alberta coal in Ontario markets, or those in the Orient and other countries. Emphasis is being placed on coal production and transportation costs, as well as improved fine coal processing;
- to develop technology that will lead to new manufacturing opportunities within Alberta; and
- to develop and apply technology that will help establish and/or improve the quality of Alberta coals or coal-derived products, as required for emerging coal-use technologies in all market areas. Processes and technologies include blending, upgrading, gasification and coal-water fuels.

# Research and Technology Programs

During 1990/91, the projects administered by the Alberta Office of Coal Research and Technology were supported by two sources of funding: Alberta/Canada Energy Resources Research Fund, and governments participating in the Western Canadian Low-Sulphur Coal to Ontario Program.

Projects under way in each of these programs are described in the following section.

## A/CERRF-Funded Projects

### Resource Evaluation

In applying technology to the challenge of making Alberta coals more competitive in various markets, a significant opportunity is created by the need to match coal quality to coal uses and to reduce costs related to coal exploration and mine planning.

Traditionally, attempts to find coal have involved outcrop inspections and expensive core-hole drilling to obtain information on subsurface rock geometry, hydrogeology and coal quality. The latter characteristic is particularly important because it indicates whether coal seams found by exploration methods are commercially valuable. Recent customer demands for tighter coal specifications, however, are causing more core holes to be drilled to isolate coals capable of satisfying particular requirements. This increases the costs of coal exploration and is an important impetus behind current research into alternative geophysical methods of evaluating coal quality in situ.

To this end, researchers are attempting to correlate seismic, direct current electric, magnetic and electromagnetic data from above-ground surveys of prospective coal fields with laboratory analyses of drilled cores. In this way, it is hoped that less-expensive methods will be developed to locate coal and evaluate its characteristics.

Since 1985, the Alberta Office of Coal Research and Technology has helped fund 13 coal resource evaluation projects, 10 of which were completed and described previously. Two of the three remaining projects were completed this year, and the other will continue next year. All are described in the following section.

Some of the completed projects are described in detail in the technology transfer booklet *Geotechnical Studies of Overburden and Coal at Alberta Coal Mines.* Copies are available at Alberta Energy/Forestry, Lands and Wildlife information centres in Calgary and Edmonton.

## Downhole Geophysical Characterization of Overburden

TRANSALTA UTILITIES CORPORATION (CALGARY) AND OTHER PARTICIPANTS[1]

This research project was initiated in 1986 to study the practical application of downhole geophysics to the quantitative determination of geotechnical and hydrological parameters in overburden materials. The objective was to identify and refine methods that will improve the collection of geotechnical and hydrological data for open-pit coal and oil sands mines in western Canada. It is believed this will lead to improved levels of confidence for designing mines, and could lower operating costs, improve safety and reduce the environmental impact of mining operations.

Currently, most of the data needed to design and operate a typical open-pit mine comes from core samples taken from exploration boreholes. These cores are analysed for the various physical characteristics that affect mine design and cost. Core drilling and laboratory analyses are expensive, however, causing mine designs to be based on a limited amount of data.

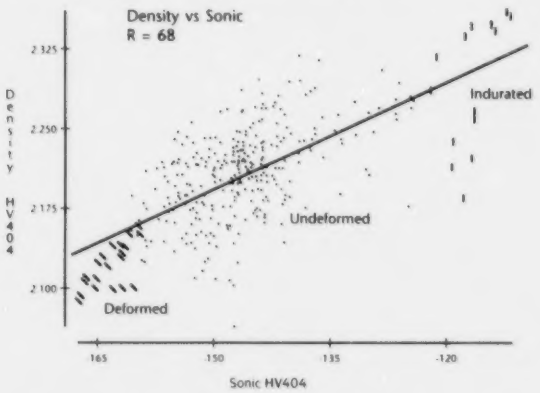
It is believed that downhole geophysics could provide large amounts of supplementary information on overburden characteristics at a low cost. Although the use of instrumentation for downhole geophysical measurement is well established, this project was undertaken because it remained to be shown that quantitative interpretation of data for physical characteristics could be achieved for Alberta's mining conditions.

After an initial literature review, promising geophysical methods were identified and evaluated during the early phases of this research. Subsequently, some of the participating companies supplied sets of downhole geophysical, geotechnical and hydrological data from Alberta coal and oil sands mines to establish correlations between geophysical log responses and the information of interest.

Geophysical logs were reviewed to find sets from drillholes in which geotechnical parameters had been determined on samples taken from known depths, or where hydrological tests had been conducted over a specified interval. Much of the data proved to be unsuitable for quantitative analysis, however. For example, depth mismatches were discovered between the geophysical logs and the geotechnical and hydrological information. Also, it was found that individual participants reported data differently, and used different calibration and correction routines. It was felt that improved data handling and analysis procedures were needed before operating mines could make practical use of quantitative log analysis. Therefore, expanded data sets were required.

Subsequent work on one of the geotechnical data sets demonstrated that improved data correction and analysis procedures are effective for strengthening the correlations.

**Example of good correlation, density vs sonic.**




Thus, several conclusions were reached as a result of this added work. They were:

- data related to geotechnical and groundwater problems can be derived from geophysical logs and can be used to supplement data obtained by more expensive conventional means, such as core testing;
- the relationships between log response and geotechnical and hydrologic factors are site-specific and must be substantiated at each new site;
- quantitative log analysis by computer should be used to provide information that is not available from standard visual inspection of paper log charts;
- to avoid misleading conclusions, log interpretations should be done by people who are thoroughly familiar with the algorithms used and the geology and hydrology of the site;
- if geophysical logs are to be interpreted quantitatively, the equipment must be calibrated

[1] Other participants in this project, in addition to the Office, were: Fording Coal Limited, Manalta Coal Ltd., Monenco Consultants Limited, Suncor Inc., Syncrude Canada Ltd., Klohn Leonoff Ltd., Golder Associates, Terracon Geotechnique Ltd., Atomic Energy of Canada Limited, Saskatchewan Power Corporation, BPB Wireline Services Limited, N. Wade Holdings, Coal Mining Research Company, Alberta Research Council, University of Alberta, CANMET, and the Department of Western Economic Diversification. Expert advice was provided by W.S. Keys of Geokeys and C.J. Mwenifumbo of the Geological Survey of Canada.

properly, logs must be checked for extraneous effects, and corroborating core samples must be taken carefully after the geophysical logs are examined;

- before quantitative log analysis can begin, certain actions must be taken to ensure that depths and drilling effects are corrected, and beds thinner than the instrumental limits of resolution are excluded or corrected; and
- all logs should be provided both as paper printouts and in digital form.

Satisfactory correlations were obtained between several types of standard geophysical logs - such as sonic, density, neutron, gamma caliper and resistivity - and a variety of geotechnical parameters. These included moisture content, liquid and plastic limits, bulk and dry density, plasticity index and uniaxial compressive strength.

The sonic log gave the best indication of the water table location in both clay-rich and sandy material, while resistivity, neutron and density logs could detect the water table under some conditions.

It was recommended that a suite of logs including sonic, resistivity, neutron and density should be run and interpreted together for increased confidence in recognizing the water table.

For best results in detecting and evaluating glacially deformed bedrock, it was recommended that sonic, density, neutron and caliper logs should be run and interpreted together.

The spectral gamma log proved to be capable of identifying bentonite and montmorillonitic clays that cause problems for pit-wall stability.

From the evaluation of other geophysical tools, the following were concluded:

- a full-wave sonic log can provide data used in calculating rock properties that are applicable in mining and geotechnical engineering; and
- an acoustic-televiewer can provide high-resolution information on the strike and dip of bedding, and on the location, orientation and character of secondary porosity, such as in fractures and solution openings.

Finally, it was recommended that certain steps should be taken if a quantitative log interpretation program is to be implemented at a mine.

They are:

- obtain geophysical log data in digital form;
- ensure that the quality of data in the log is suitable for quantitative analysis; and
- ensure that core samples are taken, or hydrological tests are carried out with reference to the geophysical logs so that the depth correspondence between them is known with certainty.

***Publications***

Hoffman, G.L, M.M. Fenton and J.G. Pawlowicz. 1991. Downhole Geophysics Project. 1986 - 1990. Final Report. TransAlta Utilities Corporation.

TransAlta Utilities Corporation. 1989. Downhole Geophysics Project Phase IIIA Progress Report.

TransAlta Utilities Corporation. 1988. Determining Geotechnical and Hydrogeological Parameters Using Downhole Geophysics in the Canadian Plains: Phase II. Correlations of Existing Data.

TransAlta Utilities Corporation. 1987. Determining Geotechnical and Hydrogeological Parameters Using Downhole Geophysics in the Canadian Plains: Phase I. A Review of Potential Applications.

## Surface Geophysical Techniques for Foothills and Mountain Coalfield Exploration

ESSO RESOURCES CANADA LIMITED (CALGARY) AND OTHER PARTICIPANTS[1]

The objective of this project was to test and evaluate the application of high-resolution, surface geophysical techniques for defining coal geology and mining targets in a variety of moderately complex topographic and geologic settings in the foothills and mountains regions.

This work was an extension of earlier investigations at three coal-mines in the plains region. While 50 years' experience with surface geophysical methods in petroleum and metal exploration suggests that suitable measurement technology is available, the economic value of these techniques in coal exploration is still uncertain.

For example, it is known that high-resolution geophysical methods demand better-than-standard topographical surveys. Also, steeply dipping beds must be mapped with a dense network of measurement points. The large volume of data collected from such a program demands sophisticated data management and processing techniques. Therefore, if these methods are to be useful to Alberta's coal industry, they must be at least as effective as, and less costly than, conventional drilling programs designed to obtain an equivalent amount of information.

[1] Other participants, in addition to the Office, were: Crows Nest Resources Limited, Manalta Coal Ltd., Smoky River Coal Limited, Quintette Coal Limited and Luscar Sterco (1977) Ltd.

In this three-year project, increasingly complex geological settings were investigated to accommodate the variety of geology and topography found in Alberta. The studies covered features such as folding, faulting, dipping strata and tectonically thickened coal under topography that varies from flat to rugged.

During Phase I studies carried out in 1988/89, seismic lines were run at the Smoky River and Coal Valley mines. The resulting reflection seismic profiles indicated structures generally consistent with the interpreted stratigraphy. The more complex topography at the Smoky River site, however, caused some difficulty in data processing. This led to the conclusion that better data on subsurface velocity control should be obtained from the downhole geophysical logs to ensure correct data interpretation. Also, additional work was warranted to refine and document the findings, as well as to compare the interpreted results with actual core findings. These activities were conducted in Phase II.

Phase II results from the Springhill coalfield in Nova Scotia showed that 5-m spacing of the seismic receivers (geophones) can provide better data than the normal, wider spacing in shallow depths. This reduced spacing was then used during the fieldwork at a mine near Telkwa, British Columbia. The interpretation of seismic data was confirmed by the on-site geology.

Some of the data from Phase I were reprocessed to eliminate the interference of electrical effects caused by physical conditions such as overburden and wet zones. This reprocessing was accomplished by "migrating", which matches known geology to the corresponding data and repositions the remainder of the data.

By the end of Phase II, the project had shown that useful reflection seismic profiles of the subsurface can be obtained in gently dipping, monoclinal strata underlying gently rolling topography, as well as in more geologically complex settings. The combination of several data manipulation techniques provided realistic geophysical information.

During 1990/91, Phase III work was carried out at the Coal Valley, Coleman, Mt. Leyland (Cadomin) and Quintette coalmines. Also, an evaluation was made of the costs of reflection seismic techniques versus conventional drilling methods.

New drilling at the Coal Valley site intersected a coal horizon that was predicted from the seismic profiles. The use of a radar unit at Quintette resulted in some interesting reflections, but the equipment experienced frequent breakdowns. Gravity, electromagnetic and electrical measurement methods were used at other sites.

At year-end, the geophysical results from the Phase III work were judged to be encouraging, and the final report was being prepared.

***Publication***

Coal Mining Research Company. 1989. Foothills/Mountain Surface Geophysics Project. Phase I Report. Prepared on behalf of Esso Resources Canada Limited and a joint venture group of companies.

Hoffman, G.L. and A.N. Sartorelli. 1990. Foothills/Mountain Surface Geophysics Project. Phase 2 Report. Prepared for Esso Resources Canada Limited and a joint venture group of companies.

## Coal Bed Methane: An Alberta Opportunity

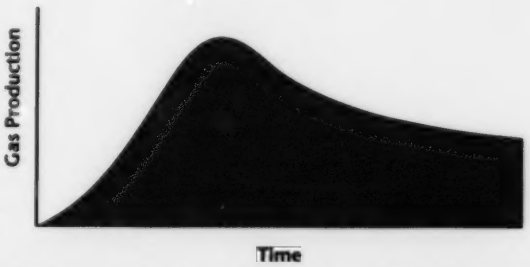
ALBERTA RESEARCH COUNCIL

An alternative to mining or gasifying coal is to extract the naturally occurring methane found in coal beds as is done now in the U.S.A. This gas is called coal bed methane (CBM).

Based on U.S. findings, it is estimated that CBM resources are widespread in Alberta, but it is not certain whether CBM can be recovered economically.

Thus, in a project initiated during the summer of 1990 by the Alberta Geological Survey (part of the Alberta Research Council), a preliminary CBM resource evaluation was performed and work was begun on establishing a database. The study is drawing on existing geological information and is being augmented with new data derived from coal chip samples. The objective is to collect information on the distribution, thickness, structure and rank of coals in Alberta.

This phase of the work was supported by the Office, CANMET and 14 oil and gas companies.




*Based on U.S. experience, coal bed methane wells might take three or more years to reach peak production, and then decline gradually for up to 10 years.*

# Preparation and Upgrading

In a world coal market characterized by considerable competition, depressed prices and emerging coal-use technologies, consumers have become more demanding about product consistency in terms of combustion characteristics, ash production and the formation of air pollutants. To satisfy these demands, techniques for removing non-combustible mineral matter and moisture in coals are constantly being improved. This not only allows producers to supply higher quality coals, but also reduces the cost of shipping non-combustible substances having no economic value.

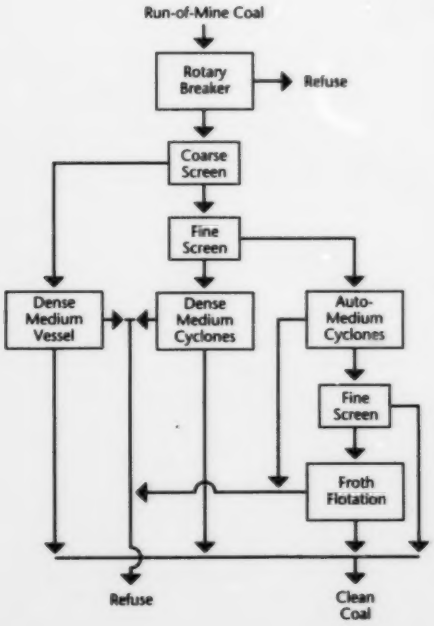
Although washing continues to be the most common coal preparation method, in Alberta it generates substantial quantities of tailings formed from the clays and fines associated with Alberta coals. These tailings represent lost product and require large storage lagoons as an environmental protection measure. Therefore, alternatives to current washing techniques are needed.

As modern fuel standards have become more stringent in response to the availability of new or improved combustion technologies, coal researchers world-wide have begun to develop methods to upgrade coal into products from which most of the nitrogen and sulphur have been removed, or which have been energy-enhanced.

These types of investigations are being pursued in Alberta, particularly those aimed at upgrading bituminous and subbituminous coals to enhance their energy content and combustion performance characteristics, and to recover more fines in the form of economically valuable products.

The results of some coal preparation and upgrading studies were reported in the technology transfer publications, *Coal Preparation Research in Alberta*; and *Studies of Fine Coal Cleaning and Upgrading Processes for Alberta Coals*. Both publications are available from Alberta Energy/Forestry, Lands and Wildlife information centres in Calgary and Edmonton.

Twenty-four coal preparation and upgrading projects have been supported by the Office since 1984. The following section contains descriptions of four that were active in 1990/91. An additional four research projects are described in the section dealing with the Western Canadian Low-Sulphur Coal to Ontario Program.




### Electrocoagulation

LUSCAR STERCO (1977) LTD. (EDSON)

It has been suggested that improving the yield efficiency of western Canadian coal preparation plants depends on finding a successful process for separating clay from coal fines. Normally, clay and shale particles suspended in process water after coals have been washed are removed in mechanical clarifiers to which chemical coagulants have been added. These coagulants are expensive, however, and process water quality is highly variable and tends to deteriorate with time. This leads to larger dosages of chemicals and rising costs.

An alternative is to use a process called electrocoagulation. In a trial at Luscar Sterco's Coal Valley mine, the process performed well, but it could not compensate for changes in clay chemistry.

Subsequently, a project was initiated in 1988/89 that involved bench-scale electrocoagulation testing by CANMET at the Coal Research Centre, Devon. The experimental work conducted in the first phase of this project determined the optimum operating conditions for the electrocoagulation technology. Initial results indicated that the technology has the potential to be economic, as well as technically effective. It was also determined that the effect of the technology can be extended by treating a relatively clean stream of water before adding it to the contaminated stream. The results indicated that a residual reaction occurred.

Thus, the electrocoagulation technology successfully precipitated particulates over a wide range of conditions, making it attractive for the treatment of high-ash fines and clays associated with Alberta thermal coals.

The next step in the project is to obtain an accurate measure of the process economics. Thus, CANMET built a larger electrocoagulation cell to provide more process control and testing of process variables. Allowance was made for a larger surface area on the electrodes, variable gaps between the electrodes, variable electrode materials and various flow rates.

At year-end, testing of the device was about to begin.

***Publication***

Donini, J.C., R.G. Frenette, K.L. Kasperski and S. Kelebek. 1989. Electrocoagulation - Final Report. Prepared by CANMET Coal Research Laboratories on behalf of Luscar Sterco (1977) Ltd.

## Coal Agglomeration Process Development

ALBERTA RESEARCH COUNCIL, DEVON

With initial funding from the Office and subsequent funding from the Electric Power Research Institute and other sources, researchers at the Alberta Research Council have spent several years developing a method for upgrading low-rank coal, using a process called oil agglomeration.

By mixing heavy oil or bitumen with coal slurries under controlled conditions, large particles called agglomerates are formed. From these, much of the undesirable mineral matter present in the original coal is removed and transferred to the water. This results in products having a higher energy content and lower ash than the parent coals. Subsequent combustion testing showed that agglomerates formed from subbituminous coals displayed excellent combustion characteristics. These results demonstrated that oil agglomeration is a promising upgrading method.

The initial technology has evolved into three processes: AGLOFLOAT, which involves agglomeration followed by froth flotation; AGFLOTHERM, which includes a thermal treatment step; and the Clean Soil Process for cleaning up spilled petroleum-based residues such as tars and oils.

In 1987/88, a consortium[1] of 22 companies and institutions began funding a pilot-scale evaluation of the processes. Since then, a continuous 6-tonne-a-day (250 kg/h) pilot plant and a continuous oil recovery unit have been built and made operational. This equipment was used to evaluate the agglomeration potential of coal samples provided by members of the consortium, and provide data to be used in calculating the process economics of a commercial-scale plant.

Test programs were carried out to study low-rank coals, bituminous coal and contaminated soils.

The investigation of low-rank coals included the following: increasing the ability to separate mineral matter selectively; understanding the mechanisms responsible for high oil recovery during thermal treatment; the conceptual design of a 250 kg/h de-oiling system for coal/oil feed with a high API oil component; and evaluation of the effects on process economics of improvements in selectivity and de-oiling.

In the bituminous coal studies, batch evaluations were made of two-stage oil agglomeration on two American coals, and the 250 kg/h agglomeration test facility was refined. Also, the performance of a pyrite separator was tested.

The contaminated soil study included developing improved methods for cleaning coal-derived tar, slag and coke from soils, and conducting demonstration tests in the 250 kg/h continuous unit with two refuse materials.

Final results from this work were presented to the consortium members at Palo Alto, California in February 1991.

***Confidential Reports***

Development of Clean Coal and Clean Soil Technologies Using Advanced Agglomeration Techniques. 1990. Volume 1: Upgrading of Low Rank Coals; The Agflotherm Process. Volume 2: Upgrading of Bituminous Coals; The Agflotherm Process. Volume 3: Soil Cleanup and Hydrocarbon Waste Treatment Process. Alberta Research Council.

[1] The consortium includes: the Electric Power Research Institute, American utility companies, state and federal governments, Canadian oil firms, coal companies, provincial governments and utility companies.

## Coal/Oil Upgrader

FORDING COAL LIMITED (CALGARY), AND OTHER PARTICIPANTS[1]

Based on the promising results thus far of the Agflotherm Process developed by the Alberta Research Council/EPRI consortium, Fording Coal Limited and PanCanadian Petroleum Limited propose to build a commercial-scale coal upgrading plant. This facility would use a specific heavy oil/subbituminous coal combination to produce an agglomerated, low-ash, low-moisture coal product, and it would simultaneously recover upgraded oil having an API gravity of 19°-25°. Thus, the ash and moisture content of the coal product would be approximately 30 to 50 per cent lower than for the parent coal, and the recovered oil would be easily hydrotreated to synthetic crude oil specifications.

This year, the first phase was initiated. Its primary objectives are to carry out laboratory studies of the rheological properties of coal agglomerates, and to select a design for a continuous oil recovery unit. The rheological studies are necessary to help optimize the processing conditions that will produce agglomerates having acceptable properties for metallurgical and thermal coal markets. Once these conditions are known, the best method for de-oiling will be chosen.

At year-end, laboratory investigations were under way at the Alberta Research Council.

[1] In addition to Fording Coal Limited and the Office, PanCanadian Petroleum Limited and CANMET provided funding for this project.

## Particle Distribution in Slurry Flow Through Tees and Manifolds

UNIVERSITY OF ALBERTA (J.H. MASLIYAH), EDMONTON

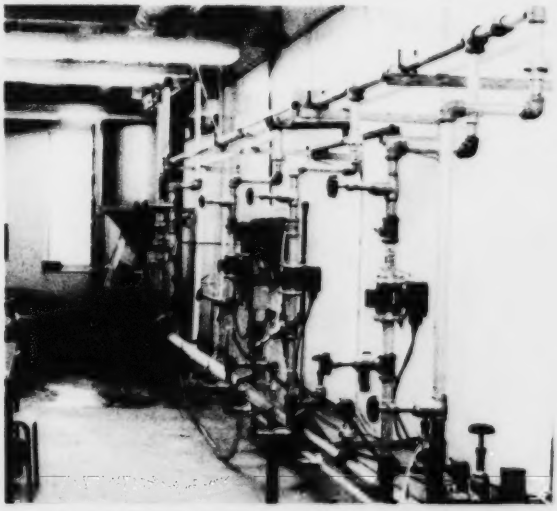
Two-phase (solid/liquid) flow through a manifold is used commonly in industry to distribute solids to various processing units. This occurs in coal preparation plants as well. Because of differences in inertia between the solid and liquid phases, the solids concentration is not always the same in various branches of a manifold. This has resulted in a need to study the relationship between solids concentration in the branches and the main pipe, as well as determining the upstream operating conditions that can affect this relationship. The objective is to achieve equal distribution of solids in each branch.

In a project carried out at the University of Alberta, a closed-loop piping arrangement having a manifold with four branches and valves was used to control slurry flow through the branches. Isokinetic and conductivity probes were installed to measure solids concentration upstream and downstream of the branch tees. Initial experiments involving sand/water slurries were conducted, using three configurations of branches: upwards, sideways and downwards. Also, three grades of sand were used: fine, medium and coarse.

It was learned that for sand-water slurries, only the sideways branch orientation gave a uniform solids distribution for the medium and coarse ranges of particle sizes, whereas a uniform solids distribution was achieved for all three piping orientations when fine sand was used.

The laboratory data were used to develop a model of solids distribution in the branches of the manifold. This empirical model, which was used to predict the concentration of solids in each branch, was found to be accurate to within 15 per cent of laboratory observations. This is considered to be adequate for design purposes.

Experiments with polyvinyl chloride particles, having a specific density of 1.2, showed the solids distribution patterns for all three orientations were equally satisfactory. This is significant because the density of polyvinyl chloride is a better approximation to that of coal than is sand, which has a specific gravity of 2.6.



*Closed-loop piping arrangement used to study solids concentration in branches of a manifold.*

***Publication***

Masliyah, J. and H. Nasr-El-Din. 1991. Particle Distribution in Slurry Flow Through Tees and Manifolds. University of Alberta.

# Combustion

Some emerging coal combustion technologies achieve optimum performance from coals having narrowly specified properties. Consequently, coal producers who wish to sell coal to the users of these technologies must be prepared to provide detailed information about the combustion characteristics of their coals. This also implies that coal producers should know how a coal will perform before it is removed from the ground. Therefore, developments in combustion technology have a direct bearing on resource evaluation and coal mining and upgrading. Furthermore, advances in the science of coal combustion make it necessary to test coals for properties other than those revealed by ultimate and proximate analyses. This means new or improved laboratory-scale combustion testing methods must be developed that not only simulate coal burning in thermal plants but, ideally, can minimize the need for the expensive, full-scale combustion tests used in the past.

Another important function of coal combustion research is to encourage coal producers, coal users and manufacturers of coal-burning equipment to become jointly involved in projects. This can lead to knowledge sharing and the enhancement of technology development in ways that benefit all parties.

With these issues in mind, the Office has supported 19 coal combustion research projects, three of which were active in 1990/91 and are described in the following section.

Also, some completed studies are described in the technology transfer publication, *Some Combustion Studies of Alberta Coals*. It is available from Alberta Energy/Forestry, Lands and Wildlife information centres.

### Program Extension to IEA Annex II Basic Coal Combustion Science

NETHERLANDS ENERGY RESEARCH FOUNDATION ECN, PETTEN

Annex II of the International Energy Agency Combustion Science Research Program involves fundamental studies and a series of investigations using semi-industrial scale coal burners to advance the science of pulverized coal combustion and minimize adverse environmental effects. Facilities of the International Flame Research Foundation (IFRF) at IJmuiden, The Netherlands, are being used.

The principal objective is to provide information that can be used to design burners capable of using a wide range of coals and producing flames having acceptable combustion characteristics, while generating few atmospheric pollutants.

The Annex II studies are funded jointly by Canada, The Netherlands, the Federal Republic of Germany and Great Britain. The Canadian contribution has been divided among CANMET, the Canadian Electrical Association, and the Alberta Office of Coal Research and Technology.

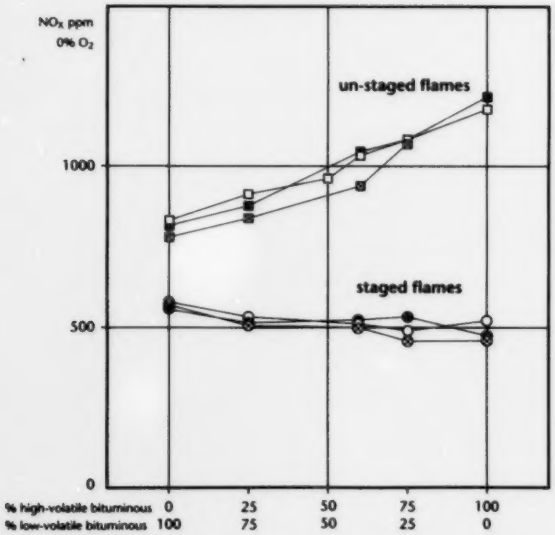
The primary objective of the research under way this year was to gain a better understanding of the influence of coal characteristics on emission levels, using the air-staging and fuel-staging processes developed at IFRF.

Included in this work were studies of the effects of coal blending on the performance of the Aerodynamically Air-Staged Burner (AASB), and the effects of mixing on $NO_x$ reduction. As well, the following research was carried out: characterizing the pyrolysis and char-burnout behaviour of low-volatile coals; developing a minimum coal characterization technique; modelling the in-flame data generated in scale-up trials; and performing preliminary studies on the modelling of $NO_x$ formation in coal flames. As well, new laser-based flow visualization techniques were developed to study the interaction between coal particles and swirling flows. At the request of utility companies, a preliminary investigation was carried out on the feasibility of including tangentially fired boilers in the study program.

As in previous work, Alberta coals were included as often as possible in the test program.

The work under this project was completed. At year-end, a project extension was being negotiated.

**Effect of coal blends on $NO_x$ emission at extreme burner conditions**




***Publications***


Dugue, J. and M.P. Abbott. 1989. LDA Measurement in Semi-industrial Gas and Coal Flames. Report on the AMT 1 Investigation. IFRF Document F 072/a/18.

Dugue, J., P. Ereaut, H. Horsman and A. Shand. 1990a. Laser Sheet Visualization in Cold Flows, Gas and Coal Flames in the IFRF Furnace No. 2. Results of the AMT 2 Investigations. IFRF Document F 072/y/19.

Dugue, J., P. Ereaut, H. Horsman and A. Shand. 1990b. Laser Sheet Visualization in Cold Flows and 2.5 MW Gas and Coal Flames. Report on the AMT 3 Investigation. IFRF Document F 072/y/20.

Knill, K.J. (n.d.) The Effect of Mixing on $NO_x$ Reduction by Coal Fuel Staging. Report on the AP 19 Investigation. IFRF Document F 037/y/21.

Knill, K.J., T.F.J. Maalman, M.E. Morgan and T. Nel. 1990. Characterization of the Combustion Behaviour of Bituminous Coals. Report on the CC 6 Investigation. IFRF Document F 088/y/12D.

Nakamura, T., J.P. Smart, W.L. van de Kamp and M.E. Morgan. 1990. Evaluation of the Behaviour of Blends in an Aerodynamically Air Staged Burner. Report on the AP 20 Investigation. IFRF Document F 037/y/22.

Visser, B.M. 1991. Mathematical Modelling of Swirling Pulverized Coal Flames. Ph.D. Thesis. Technische Universiteit, Delft.

Visser, B.M. and R. Weber. 1990. Predictions of Near Burner Zone Properties of Six Swirling Pulverized Coal Flames. Report on the MMF 3 Investigation. IFRF Document F 036/y/14.

## Coal Utilization Program Planning

ALBERTA RESEARCH COUNCIL, DEVON

The services of a combustion engineer from the Alberta Research Council were provided to the Office to oversee research activities under the International Energy Agency (IEA) Annex II project. He also represented the Office during meetings of the Canadian Technical Committee and the IEA Executive Committee for this Annex.

This year, meetings of the Canadian Technical Committee for Annex II in May and December, and one meeting of the Annex II Executive Committee were attended. Reports from the International Flame Research Institute were reviewed. A detailed presentation of IEA Annex II test results and their interpretation was given to an Alberta coal company.

A meeting of Japanese and Canadian coal scientists and industry representatives was held in Vancouver to present results of recent coal-use research. This was the final meeting of a three-year co-operative Japan-Canada joint academic research program on advanced processes for efficient uses of coal.

Next year, the project will place greater emphasis on transferring technical information about low $NO_x$ coal combustion to the Alberta industry. This information will be derived from the research under way within the IEA program.

***Publications***

Chambers, A.K. 1990. Coal Utilization Program Planning. Alberta Research Council.

## Ash Properties of Alberta Coals

ALBERTA RESEARCH COUNCIL, DEVON

Approximately 80 per cent of the coal ash produced by conventional coal-fired power plants is recovered as flyash. Assuming it has certain desirable properties, this flyash may be used as a cement additive, thereby avoiding disposal in a landfill. Since limestone injection into the furnace is currently being studied as a method for reducing sulphur oxide emissions from power plants, this project was initiated to determine whether limestone injection would also affect the cementatious properties of flyash.

Flyash samples from both Highvale and Forestburg coals were produced with a 3 kg/h combustor at the Alberta Research Council. Various limestone injection rates and injection locations were used. The produced samples of flyash, and flyash samples from operating power plants, were provided to Dr. R. Joshi at The University of Calgary for assessment of their cementatious properties.

Because difficulties with slagging in the laboratory combustor were experienced, the combustor exit was re-designed. This delayed the completion of the project.

***Publication***

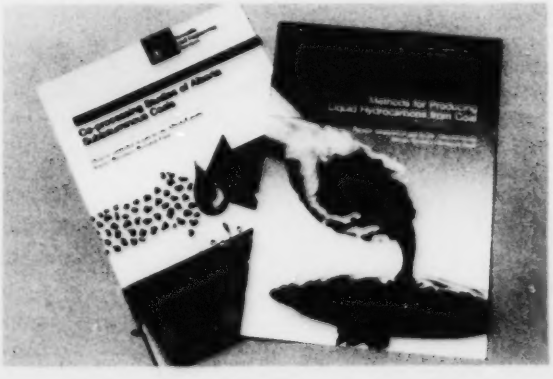
Chambers, A.K., M. Malychuk and R. Zacharkiw. 1990. Ash Properties of Alberta Coals. Alberta Research Council.

# Liquefaction/Co-processing

During the next 30 years, production of conventional crude oil from Alberta's established oil fields is expected to decline well below current levels. The rate of decline will depend on a number of factors, such as world oil prices and demand, but eventually it will become necessary to produce more synthetic crude oil from Alberta's oil sands, heavy oil and coal. Although the economics of producing oil in this manner are unattractive as long as oil prices are depressed, abundant quantities of raw materials are readily available for extraction whenever the economics become more favourable. For instance, Alberta's proven reserves of subbituminous coals could provide enough synthetic crude oil to satisfy domestic consumption for at least the next century, assuming a suitable and economic liquefaction process can be developed to convert coal to petroleum substitutes.

One conversion concept that is showing some promise, and has been studied extensively in Alberta, involves co-processing of coal and heavy oil or bitumen. This process not only provides a method for producing synthetic crude oil from coal, but may also prove to be useful in upgrading heavy oil. This and other potential liquefaction processes are under development; some may involve less severe reaction conditions than used elsewhere. Also, methods of analysing the quality of liquefaction products are being actively investigated in Alberta. Furthermore, the level of liquefaction research in Alberta has led to considerable collaboration among the various participants at Alberta Research Council, the University of Alberta and private industry.

The Office has supported 27 coal liquefaction research projects, some of which were multi-year, major efforts. Six projects, active this past year, are described in the following section.



The Office has published two technology transfer booklets on coal !iquefaction: *Co-processing Studies of Alberta Subbituminous Coals*; and *Methods for Producing Liquid Hydrocarbons from Coal.* Both are available from Alberta Energy/Forestry, Lands and Wildlife information centres.

### Co-processing Process Development

CANADIAN ENERGY DEVELOPMENTS INC., EDMONTON

Canadian Energy Developments Inc. (CED) is developing a process to make synthetic crude oil from subbituminous coal and bitumen. This process, known as co-processing, not only provides a method for producing synthetic crude oil from coal, but is also useful in upgrading heavy oil.

The overall objective of the company is to design, construct and operate a commercial-scale, co-processing upgrader in Alberta in the 1990s.

In this project, the company simultaneously developed two co-processing schemes. One of these, known as PYROSOL, is a low-severity, two-stage process. It comprises mild hydrogenation and coking in a pressurized delayed coker under a hydrogen atmosphere.

The synthetic crude product from the PYROSOL process contains approximately 10 per cent naphtha, 60 per cent middle distillate and 30 per cent heavy distillate. It has the potential to be a premium product because it contains substantial quantities of middle distillate from which aviation and diesel fuels are made.

The second co-processing scheme, the CCLC process, involves coal solvolysis in a heavy oil slurrying medium followed by moderately severe hydrogenation of the solubilized coal and heavy oil.

The synthetic crude from the CCLC process is a light distillate containing approximately 35 per cent naphtha, 45 per cent middle distillate and 20 per cent heavy distillate. The product is substantially lighter than that produced by the oil sands plants in Fort McMurray.

Interest in these processes, and co-processing in general, stems from the fact that use of low-cost coal lowers the feedstock cost and the overall production costs of these upgrading schemes below those used to upgrade heavy oil or bitumen alone.

Since this process development project began in 1986, a 2 kg per hour, two-stage hydrogenation bench-scale unit (BSU) and a 1.3 L pressurized delayed hydrocoker were used to conduct operating-severity studies. In these studies, hydrogenation pressure, temperature and reactor residence time were varied to control the distillable oil yield and maintain a high level of pitch conversion.

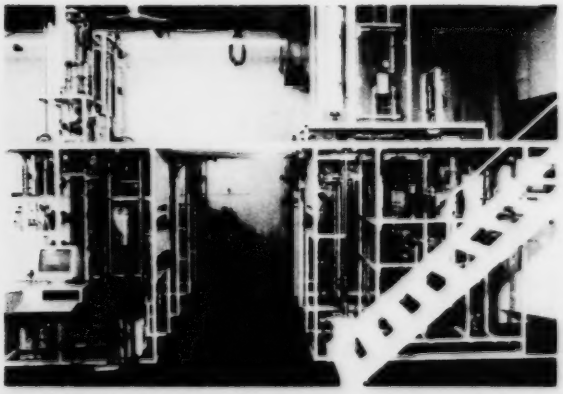
Also, a 250 kg per day continuous process demonstration unit (PDU) was commissioned to allow long duration, continuous studies to be made on a larger scale.

Over the past five years, both the PYROSOL and CCLC processes were evaluated in detail, and a large database of process conditions and yield results was established. Operating conditions were defined that yield approximately 70-72 weight per cent distillable oils from Cold Lake vacuum bottoms and subbituminous coals from the Vesta mine.

Two reactor configurations for the hydrogenation step were evaluated within the terms of an agreement between CED and Gesellschaft für Kohleverflüssigung m.b.H. (GfK) in Germany.

All tests at CED's facilities were performed in a co-current upflow reactor configuration, while those carried out at GfK used a counterflow reactor. The results showed that the counterflow reactor has certain significant advantages over the co-current upflow reactor. Therefore, a new project is now under way (see Coal/Oil Co-processing Using a Counterflow Reactor) to develop further the CCLC co-processing scheme using counterflow technology.

In co-operation with the Alberta Research Council, secondary upgrading processes were defined for the treatment of distillable oils derived from the two CED co-processing methods. These procedures produced synthetic crude oil or blending streams for marketable products.



*The PYROSOL and CCLC coal/heavy oil co-processing methods of Canadian Energy Developments Inc. were tested and developed on this 250 kg per day process demonstration unit.*

A Canadian patent was granted to CED, and other patent applications have been filed in the U.S.A., Germany and Canada.

Based on the co-processing technology developed during this project, a proposal has been made to industry and governments to build a commercial-scale upgrader at the mouth of an Alberta coal mine. It would produce 28 000 barrels per day of synthetic crude oil.

At year-end, the final project report was being completed.

***Publications***

Canadian Energy Developments Inc. 1990. Coprocessing Process Development. Final Report.

Canadian Patent #504 954, "Coprocessing of Coal and Heavy Oil."

## Combined Processing of Coal, Heavy Oil and Natural Gas

UNIVERSITY OF ALBERTA (M.R. GRAY), EDMONTON

One of the major costs of coal/heavy oil co-processing is incurred during the production of gaseous hydrogen, which is currently obtained by steam reforming natural gas. Although hydrogen gas is important because it suppresses the formation of coke in the co-processing reactor, and helps to upgrade the liquids from coal and heavy oil by raising the hydrogen:carbon ratio, a less-expensive source of hydrogen would enhance significantly the economics of co-processing.

In a previous study funded by the Office, the use of high-pressure natural gas was used directly as the hydrogenation agent. In the presence of tetralin and $Fe_2O_3$ catalyst, the conversion of Highvale subbituminous coal to toluene-soluble products was equal to or higher than that from hydrogen gas liquefaction. Thus, the substitution of methane (natural gas) for hydrogen would make co-processing more economically attractive if comparable product quality and yield can be achieved.

Last year, a new project was initiated to determine the yields and product qualities from the continued processing of coal, heavy oil and natural gas. It was also to provide the data necessary to evaluate the feasibility of the combined processing concept.

Using a 150 mL autoclave reactor and a reaction temperature of 430°C, a series of experiments was carried out under hydrogen, nitrogen or methane at 1 000 psia in the presence of an iron oxide catalyst. Three types of reactions were studied: coal liquefaction using tetralin as a solvent; model compound reactions using a mixture of naphthalene, phenanthrene and tetralin; and co-processing of coal and bitumen.

Thus far, it was found that the nitrogen and methane atmospheres produced similar results, and both were inferior to hydrogen. Use of deuterium labelling showed that much of the gas-phase methane was not incorporated into liquid products.

At year-end, additional experiments were under way to explain this behaviour.

## Co-processing of Coal with Molten Halide Catalysts

UNIVERSITY OF CALGARY (A. CHAKMA), CALGARY

In this project, the principal objective is to liquefy an Alberta subbituminous coal and simultaneously upgrade bitumen in the presence of molten halide catalysts under hydrogen pressure. It is believed this might increase liquid yields, and decrease the asphaltene fraction and increase the maltene fraction of the products.

After the experimental apparatus was commissioned and experimentation commenced, some problems with controlling the heating system were encountered. These were overcome and several metal chlorides and their mixtures were tested. In total, approximately 50 experiments were planned at 400°C in the presence of hydrogen.

At year-end, the experimental work had been completed and the final report was being written.

## Product and Process Characterization

ALBERTA RESEARCH COUNCIL, DEVON

The objective of this multi-year project was to develop an understanding of the chemical changes that occur when coal and bitumen react in co-processing schemes. This should help provide insight into the various mechanisms by which coal and bitumen combine to form products, and could lead to process improvements. The project involved analytical characterization of co-processing products to determine better the reaction pathway occurring when coal and bitumen are co-processed to produce synthetic crudes.

The knowledge gained during this project was the result of several laboratory activities. They included the following: evaluating samples of co-processed products by Nuclear Magnetic Resonance for Cetane Index; analysing resin samples obtained from the bench-unit experiments of Canadian Energy Developments Inc; and performing Field Ionization Mass Spectrometer analysis on samples of secondary products (middle distillate fractions).

Also, Cetane Index measurements were made of middle distillates from co-processing to provide useful information in evaluating these liquid products as potential feedstocks for refineries. These distillates were also separated into saturates and aromatics to provide methods for evaluating process chemistry. Also, several separation methods were tested to obtain the overall composition of feedstocks for, and the reaction products of, co-processing schemes.

In addition, asphaltene and resin fractions separated by some of these techniques were analysed by gel permeation chromatography and other methods. Then, the developed methods were tested by using them to analyse two samples of co-processed products from Canadian Energy Developments Inc.

In this final year of the project, a laboratory manual was prepared. It describes modern analytical procedures and their application to the study of coal-derived liquids. This publication should be a valuable guide for coal-liquefaction researchers.

The project was completed.

***Publications***


Selucky, M.L. 1991. Coal Liquid Characterization Methods. Alberta Research Council.

Selucky, M.L. 1990. Product and Process Characterization Report for 1988-1989. Alberta Research Council.

Selucky, M.L., D. Bizzotto and T. Manske. 1989a. Detailed Analysis of Feed and Product Asphaltenes in Products from Coal Bitumen Co-Processing. Presentation at the American Chemical Society Spring Symposium, Dallas, Texas.

Selucky, M.L., D. Bizzotto and T. Manske. 1989b. Detailed Analysis of Feed and Product Asphaltenes in Products from Coal Bitumen Co-processing. American Chemical Society, Petroleum Chemistry Division, Preprints, 84 (2) 214.

Selucky, M.L., R. Wasel, B. Rawluk and T. Taerum. 1989. Application of 1H and 13C NMR for the Evaluation of Cetane Index of Middle Distillates. Presentation at the Canadian General Standards Board Meeting, Edmonton, Alberta.

Selucky, M.L., R. Wasel, B. Rebus and T. Taerum. 1989. Application of 13C and 1H NMR for Evaluation of Cetane Rating of Middle Distillates. Presentation at the Confab '89 Conference, Laramie, Wyoming.

## Coal/Heavy Oil Co-processing Management Committee

In August 1988, a management committee[1] was formed to assess the rationale and need for further development of technology suitable for co-processing of coal and heavy oil.

Several feasibility studies had indicated that co-processing is a less-expensive method than direct liquefaction for producing synthetic fuels from coal, and it might even be an alternative to the current method for upgrading heavy oil/bitumen to synthetic crude oils. Therefore, the management committee initiated a two-phase investigation to identify the relative merits and economics of coal/oil co-processing compared to heavy oil upgrading. The study is also examining strategies affecting commercial development of co-processing technologies in Alberta.

The first phase of the project was completed in 1989/90. Under the leadership of the Alberta Oil Sands Technology and Research Authority (AOSTRA), and with financial contributions from some of the technical committee members, it was found that the economics of co-processing are essentially equivalent to those of heavy oil upgrading at today's feedstock prices. The strategic factors that can have a significant effect on the commercial development of co-processing are: feedstocks; plant location; infrastructure; technology and plant capacity.

The second phase of the work began in 1990/91. Its objectives are to define and explore the opportunities in Alberta that will be necessary before a commercial co-processing venture can begin. In addition to investigating the strategic factors identified in Phase I, marketing requirements and environmental regulatory issues are being studied during the second phase.

Contractors responsible for studying individual strategic factors were hired at year-end.

[1] Phase I participants were: Canadian Occidental Petroleum Ltd., Alberta Power Limited, Gulf Canada Resources Limited, Husky Oil Operations Ltd., Shell Canada Limited, TransAlta Utilities Corporation, Amoco Canada Petroleum Company Ltd., Mitsui SRC Development Co. Ltd., Saskatchewan Energy and Mines, Alberta Oil Sands Technology and Research Authority, and the Alberta Office of Coal Research and Technology.

Phase II participants are: Canadian Occidental Petroleum Ltd., Husky Oil Operations Ltd., Mitsui SRC Development Co. Ltd., TransAlta Utilities Corporation, Canadian Energy Developments Inc., Esso Resources Canada Limited, PanCanadian Petroleum Limited, Manalta Coal Ltd., VEBA Oel, Alberta Research Council, CANMET, Alberta Oil Sands Technology and Research Authority, and the Alberta Office of Coal Research and Technology.

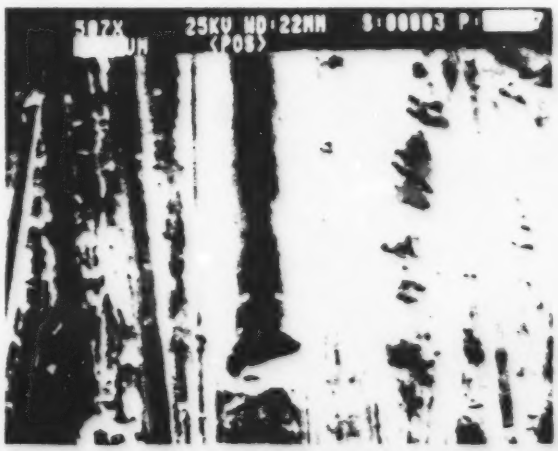
## Specialty Chemicals from Coal-Derived Liquids

ALBERTA RESEARCH COUNCIL, DEVON

Both the distillable and non-distillable liquid products from coal conversion reactions are capable of providing polycondensed aromatic feedstocks for value-added products, such as carbon fibres and fine chemicals. Because the development of processes for side-chain removal and for carbon fibre production from pitch may create a coal-based secondary industry in Alberta, a project was begun last year at the Alberta Research Council to explore this opportunity.

In particular, this project has focused on methods for making carbon fibre. This material is being used increasingly in products such as reinforced concrete, engineering plastics employed in automobile and aerospace components, and as a replacement for asbestos.

In the Alberta Research Council project, the objective is to make general purpose carbon fibre (GPCF) from the pitch produced by the liquefaction of Alberta coal. Thus far, it has been found that carbon fibre production requires several steps. These include pitch treatment, filament spinning, filament stabilization and final heat treatment. Various options within these steps were examined, including pitch modification, measuring the viscosity of modified pitch, the equipment for making filaments, and conditions for stabilizing the surface of filaments. A final product was obtained, and its physical properties were judged to be comparable to those of commercial-grade GPCF.




*Scanning Electron Micrograph of carbon fibre produced from coal liquefaction pitch.*

Coal-derived distillables contain two to five polycondensed aromatics, although random locations of side-chains on aromatic rings give a mixture of isomers. If side-chains are removed, the products can be isolated readily by conventional separation techniques. These components could be used as intermediates for further synthesis of final products, such as fine chemicals, monomers for unique plastics and pharmaceuticals. In studying various processes for the dealkylation of coal-derived liquids, one promising condition was found. It produced naphthalene (25.3 per cent), indene (16.5 per cent), and 2-methylnaphthalene (11.6 per cent).

The project will continue next year.

***Publications***

Ohuchi, T. and A.K. Chambers. 1991. Production Capacity of Carbon Fiber and Industrial Application of General Purpose Carbon Fiber. Alberta Research Council.

Ohuchi, T., M. Carmichael and A. Chambers. 1990. Specialty Chemicals and Carbon Fibre from Coal Derived Liquids. Alberta Research Council.

## Coal/Oil Co-processing Using a Counterflow Reactor

CANADIAN ENERGY DEVELOPMENTS INC., EDMONTON[1]

Another promising process has been evolving in Germany, concurrent with the refinements being made by Canadian Energy Developments Inc. (CED) to the PYROSOL and CCLC co-processing methods for making synthetic crude oils from Alberta subbituminous coals and bitumen,

It has been shown that use of a counterflow reactor system, in which the feedstocks move downward and contact upward-moving hydrogen, has certain inherent advantages over the co-current, upflow reactor technology used previously by CED and other process developers. The German tests showed that a counterflow reactor is capable of performing equally well in direct coal liquefaction, co-processing and heavy oil upgrading.

Therefore, a new project was initiated this year to test the counterflow process with Alberta coal and heavy oil.

Thus far, the process development unit has been modified to the counterflow configuration and two continuous long-duration reactor runs were completed. The first lasted for 32 days, during which the unit was commissioned and certain operating and mechanical problems were solved. The second run lasted approximately 300 hours. Distillable oil yields of up to 68 weight per cent (daf basis) were obtained from 60 weight per cent Cold Lake vacuum bottoms and 40 weight per cent Vesta subbituminous coal. This run demonstrated that the counterflow reactor was both suitable for co-processing and efficient recovery of the produced exothermic heat.

At year-end, adjustments were planned to raise the oil yield to above 70 weight per cent.

[1] In addition to the Office, Canadian Energy Developments Inc. and the Alberta Oil Sands Technology and Research Authority provided funds for this project.

# Gasification

Because coal is used to produce more than 90 per cent of Alberta's electrical power, the economic and environmental importance of efficient power generation from coal will be crucial to Alberta's development for the foreseeable future. Integrated Coal Gasification Combined Cycle (IGCC) is regarded by the power-generation industry as the technology of choice for electrical power production from coal. IGCC is being seriously considered by industry because it is economically competitive with conventional coal-combustion systems and it has demonstrated unparalleled performance in emission control. IGCC offers the ability to reduce $NO_x$ and $SO_x$ emissions below levels currently required by regulation or recommended by guidelines. The increased efficiency of IGCC relative to other coal-based technologies results in approximately 15 to 20 per cent less carbon dioxide production per unit of electrical output. Current IGCC technology can permit essentially complete removal of $CO_2$ from the stack gas, if required.

Alberta's coals are unique in that they have a low-sulphur content and high reactivity. Most current coal-utilization technologies, however, have been developed for coals that contain more sulphur and are less reactive.

Thus far, 11 research projects have been initiated to study the gasification properties of Alberta coals and to quantify their behaviour when used in several existing IGCC systems.

One of these projects was active in 1990/91, and one additional project was supported under the Western Canadian Low-Sulphur Coal to Ontario Program.

Gasification projects completed thus far are described in two technology transfer booklets: *Gasification of Western Canadian Coals*, and *Gasification of Alberta Coals*. Also, the publication *Development of Clean Coal Technologies for Alberta* contains information on Integrated Gasification Combined Cycle processes. All three publications are available from Alberta Energy/ Forestry, Lands and Wildlife information centres in Calgary and Edmonton.

### Canadian Gasification R&D Steering Committee

In 1987, a consortium[1] of sponsors, headed by TransAlta Utilities Corporation of Calgary, funded an investigation of coal gasification technologies and applications. This included determining the potential of using Alberta coal in existing or emerging systems.

The study concluded that Integrated Gasification Combined Cycle (IGCC) systems now under development are demonstrating several advantages over current, coal-fired thermal technology for electricity generation.

Therefore, it was recommended that Alberta coal producers and researchers should become actively involved in IGCC developments. Subsequently, the Canadian Coal Gasification Technical Committee (since renamed Canadian Gasification R&D Steering Committee[2]) was formed to oversee and fund coal gasification projects comprising a multi-year research program. The objectives of this program were:

- to design and build a 100 MW (electrical) prototype IGCC plant in Canada by 1994;
- to establish and standardize coal gasification testing methods for Canadian laboratories; and
- to facilitate performance evaluations of Canadian coals in various coal gasification technologies.

[1] The consortium comprised: TransAlta Utilities Corporation (with Monenco Consultants Limited as the principal subcontractor), Alberta Power Limited, Luscar Ltd., Saskatchewan Power Corporation, Atlantic Coal Institute and the Alberta Office of Coal Research and Technology.

[2] As of December 31, 1990, participants in the Canadian Coal Gasification Technical Committee were: TransAlta Utilities Corporation, Esso Resources Canada Limited, Edmonton Power Limited, Shell Canada Limited, Gulf Canada Corporation, Luscar Ltd., SaskPower, Westar Mining Ltd., Monenco Consultants Limited, Alberta Power Limited, The Coal Association of Canada, Nova Scotia Department of Mines and Energy, Saskatchewan Department of Energy and Mines, CANMET, University of Waterloo, University of British Columbia, and the Alberta Office of Coal Research and Technology, assisted by the Alberta Research Council.

The program was divided into five major elements. They are:

- Technology assessment;
- Coal characterization;
- Exploratory experimentation;
- Engineering systems design; and
- Applications research.

Projects associated with these elements were initiated, and they covered most of the major steps involved in gasification, from preparing coal as feedstock to emission control. Projects supported by members of the Committee are listed below.

During 1990, the Committee members agreed that many of the original objectives had been met. Therefore, research priorities were revised as follows:

- evaluate materials;
- model IGCC and gasification processes;
- quantify emissions;
- evaluate fuels preparation;
- conduct gasification tests;
- optimize designs; and
- evaluate uses for by-products.

Also this year, five coals were shipped to Japan for testing in the airblown gasification process being developed by the Central Research Institute of Electric Power Industry (CRIEPI). Coal from the Obed Mountain mine was selected for additional testing in the two-tonne a day plant. In separate testing, Coal Valley coal showed promising results when used in both the CRIEPI and HYCOL gasification processes.

Several coals were evaluated in the Dow gasification process, and five coals, including samples from the Highvale and Paintearth mines were tested at the University of British Columbia. In this pilot-scale, fluidized bed gasifier, sulphur capture occurs simultaneously with gasification. The final report was distributed to project sponsors.

In September 1990, the Committee held a joint meeting with Japanese members of the Canada/ Japan Joint Academic Research Program on Finding Efficient Uses for Coal. Several papers were given on recent developments in coal gasification in Japan, and some members of the Committee gave presentations on research that is under way in Canada.

Projects Supported by Members of the Committee:

| Project | Completion Date |
|---|---|
| Gasification of Western Canadian Coals | 1987 |
| High Temperature, High Pressure Gas Stream Cleanup | 1987 |
| Evaluation of the KRW IGCC Demonstration Stage Process for Conversion of Alberta's Highvale Coal to Electricity | 1988 |
| Economic Studies of Gasification Applications: Phase I Methanol Co-production | 1988 |
| Economic Studies of Gasification Applications: Phase II Hydrogen and Carbon Dioxide Co-production with Electricity | 1988 |
| Gasification of Canadian Coals using Pilot Plant Pressurized Gasifier | 1989 |
| Evaluation of Canadian Coals for Gasification with Texaco, BGL and Shell Technology | 1989 |
| Data Base of Canadian Coals for Gasification | 1989 |
| Evaluation of IGCC for Canadian Utility Applications | 1989 |
| Alberta Research Council Gasification R&D | 1990 |
| Pilot Plant Testing of Simultaneous Sulphur Capture During Fluid Bed Gasification | 1990 |
| Dow Gasification Evaluation | Ongoing |

## Gasification Properties of Alberta Coals

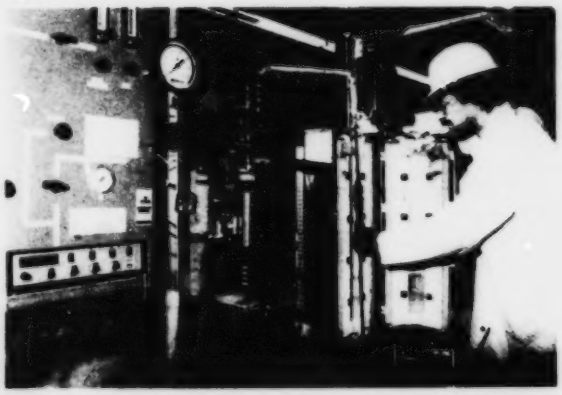
ALBERTA RESEARCH COUNCIL, DEVON

For the past two years, investigations have been under way at the Alberta Research Council to find an inexpensive disposable sorbent for use in removal of pollutant species from gasifiers operating with low-sulphur Alberta coals. This substance would be used in a sorbent injection system and could improve considerably the efficiency and economics of coal gasification processes. The principal pollutants of interest are hydrogen sulphide, carbonyl sulphide and ammonia.

In earlier laboratory-scale studies, it was found that calcium-based sorbents were the most promising for capture of sulphur species produced by coal gasification.

This year, studies were performed in co-operation with CANMET to test limestone injection on a pilot-scale gasifier. This unit is installed at the CANMET Bell's Corners laboratory. A sorbent injection unit was built and sent to the CANMET laboratory, where an Alberta Research Council staff member participated in the limestone injection tests involving the gasification of Highvale coal.

Initial results were promising, and future work using the pilot-scale gasifier was recommended.



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Kovacik, G. A.K. Chambers and B. Ozum. 1988a. Staff Training: Gasification Process Research. Alberta Research Council.

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Kovacik, G., A.K. Chambers and B. Ozum. 1988c. Gasification Characterization of Alberta Coals. Alberta Research Council.

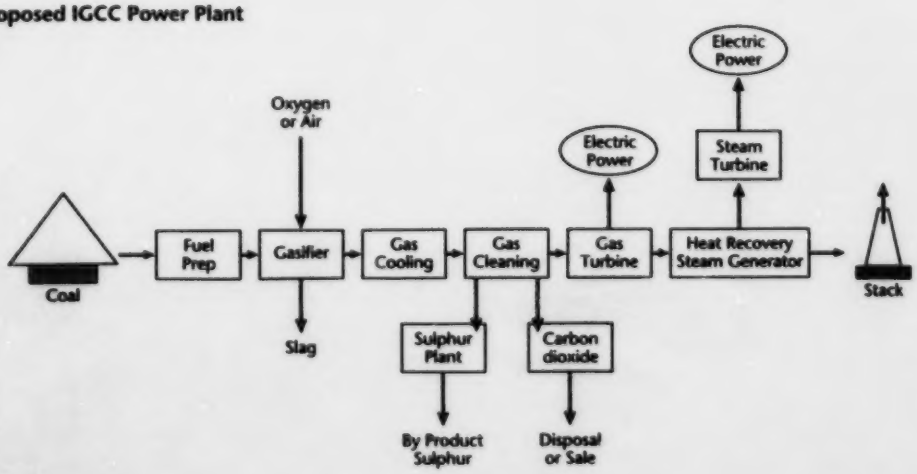
Kovacik, G., A.K. Chambers and B. Ozum. 1988d. Laboratory-Scale Facilities to Study Gasification Properties of Alberta Coals. Alberta Research Council.

Kovacik, G., M. Oguztoreli, A.K. Chambers and B. Ozum. 1990. Equilibrium Calculations in Coal Gasification. Int. J. Hydrogen Energy, 15:2, 125-131.

Kovacik, G., B. Ozum and A.K. Chambers. 1989. Gasification Properties of Alberta Coals. Alberta Research Council.

Kovacik, G., B. Ozum, D.E. Ungarian and A.K. Chambers. 1990. Gasification Properties of Alberta Coals. Alberta Research Council.


**Proposed IGCC Power Plant**



### Canada/Japan Collaboration on Coal Gasification Research

ALBERTA RESEARCH COUNCIL, EDMONTON

In 1981, Japanese and Canadian researchers reached agreement on a collaborative program to carry out coal liquefaction research and development. Since then, this has evolved into a coal conversion research effort, and in recent years the focus has begun to shift toward coal gasification.

Following a visit in 1988 to Japan by a team of Canadian coal researchers, it was observed that Japan was making significant strides in coal gasification research, and that every effort should be made to have Canadian coals included in tests carried out in Japan.

While the Office has supported the involvement of Alberta Research Council personnel in past Canada/Japan coal conversion activities, it was decided this year to initiate a separate project specifically for collaborative gasification work.

The principal objectives are to develop new research programs, arrange and attend meetings, ship coal samples to Japan, and inform the Alberta coal industry of technical developments in this field.

***Publication***

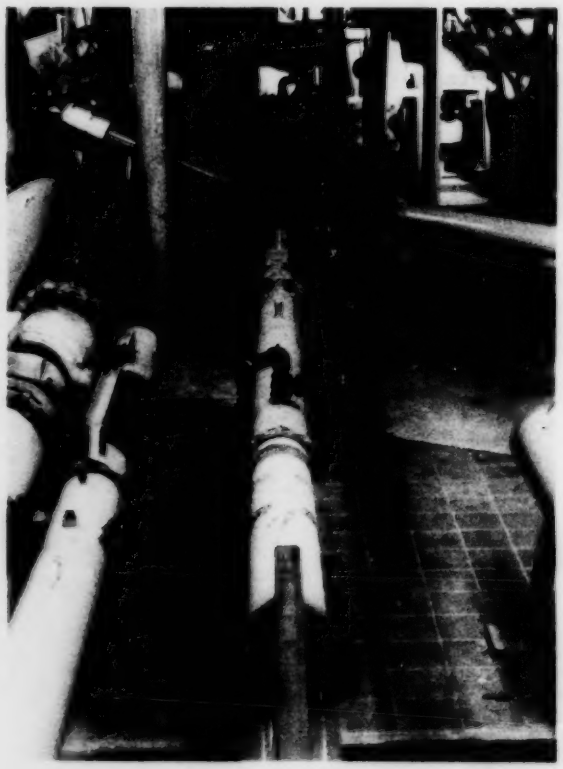
Silveston, P.L. 1989. Coal Conversion Research in Japan. Report of the Canadian Visiting Team.

## Transportation

Except for subbituminous coal, which is consumed in Alberta at mine-mouth thermal power plants, Alberta's other coal products must be shipped long distances to market. Therefore, transportation costs make a significant contribution to the delivered costs of Alberta coals. For example, transportation by rail accounts for 35 per cent of all the costs to mine, clean and deliver Alberta coals to Pacific ports.

As an alternative to rail haul, the concept of moving coal slurries to market in a pipeline has been the subject of two major feasibility studies in Alberta since 1980. Each investigation indicated that, within certain limits, coal pipelining to the west coast or Ontario is viable.

Given the current priority of reducing the delivered cost of Alberta coal in Ontario, five additional coal pipelining investigations were carried out in recent years. One is described in the following section. Another two projects are found in the Enhanced Oil Recovery section of this report, and one additional project is described in the Western Canadian Low-Sulphur Coal to Ontario section.



## Coal Slurry Technology

SALZGITTER INDUSTRIEBAU GmbH, FEDERAL REPUBLIC OF GERMANY

In this collaborative[1] project, an investigation is being made of the technical and economic feasibility of producing, transporting by pipeline and burning a coal-water slurry fuel made from Alberta coal using Salzgitter's DENSECOAL process. This is an alternative transportation scheme for lowering the delivered cost of coal in Ontario and other markets.

In previous years, it was found that coal slurries made from medium-volatile Alberta coal and a blend of medium-volatile and high-volatile Alberta coals exhibited stable behaviour and could be pumped long distances. Some difficulties arose, however, when combustion tests were performed; the results of these tests were unsatisfactory. It was found last year that atomization of the slurry was critical for acceptable combustion. It was suggested that changes be made to improve the spray quality of the slurries, and a higher proportion of more volatile coal be incorporated into the coal blend.

In 1989/90, the combustion program was redesigned and the slurries were agitated during transport to avoid settling. Combustion testing was performed by a private firm in California on only the slurry made from the medium-volatile bituminous coal (called DENSECOAL-P). Both the atomization and combustion tests were successful. Using these test results, computer modelling was carried out to determine the degree of "derating" in boiler performance caused by the use of slurries in place of fuel oil. Modelling was also used to generate boiler conversion costs. Capital and operating costs were estimated for two sizes of DENSECOAL plants: 1 million tonnes and two million tonnes a year.

Trans Mountain Pipe Line Company Ltd. and Interprovincial Pipe Line Limited, in co-operation with Salzgitter, produced capital and operating costs for the western pipeline route to Pacific markets and the eastern pipeline route to the Ontario market, respectively. Salzgitter provided additional engineering data produced through comprehensive testing in Germany.

At this juncture, it was concluded that DENSECOAL technology produced a slurry fuel having an acceptable viscosity for pipeline transport, and it was sufficiently stable for shipment to remote markets. More work, however, was needed to define the combustion characteristics and supply economics.

Two samples of DENSECOAL-P underwent large-scale combustion testing by CANMET at Bells Corners. A flame tunnel furnace was used to evaluate the effect of combustion air temperature on the combustion efficiency and carbon burnout characteristics. It was concluded that the combustion and heat transfer performance of DENSECOAL-P was similar to that of No. 6 fuel oil, provided that special care was taken in fuel handling and atomization.

At the conclusion of this project, some doubts remained about the suitability of medium-volatile bituminous coals for use in DENSECOAL slurries. Also, it was found that the delivered price of DENSECOAL in both Vancouver and Ontario was higher than desired. As a result, several recommendations were made to reduce these costs, especially concerning the use of chemicals during slurry preparation.

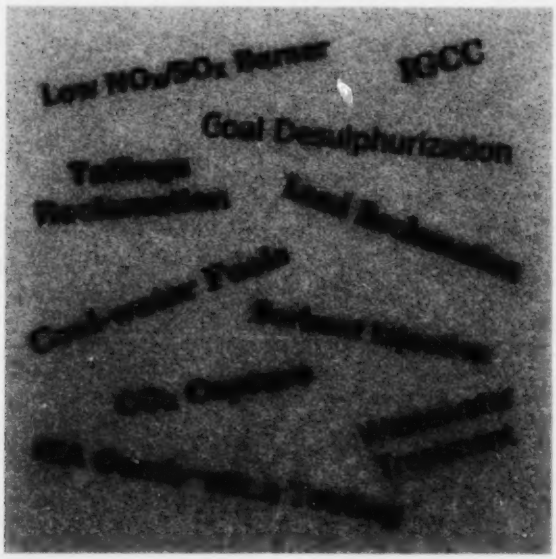
All reports produced for this project are confidential.

[1] At various stages of this project, funding was provided by: Ontario Hydro, Maritime Electric Company Limited, Trans Mountain Pipe Line Company Ltd., Interprovincial Pipe Line Limited, several coal producers, Bundesministerium für Forschung und Technologie (Germany), and Energy, Mines and Resources Canada, in addition to the Alberta Office of Coal Research and Technology.

# Environment

Environmental issues must be addressed in each of the projects funded by the Alberta Office of Coal Research and Technology, whether the concern is land reclamation, habitat disturbance or the discharge of contaminants into water bodies or the atmosphere.

This is consistent with a growing awareness by Alberta's coal producers that economic development and environmental protection must proceed hand-in-hand. For example, when mining activities cease in open-pit mines, the previously removed overburden must be replaced in such a manner that native vegetation or crops can be grown. Also, in considering future electricity-generating technologies for Alberta, utility companies find coal gasification to be attractive, partly because it produces fewer air emissions. As well, one of the most important advantages of using low-sulphur Alberta coal in Ontario is that fewer sulphur oxides will be produced during combustion. These are but a few examples of the environmental considerations inherent in each project supported by the Office. One project wholly concerned with environmental protection is described in the following section.




### A State-of-the-Art Review on $CO_2$ Separation/Disposal Technologies

TRANSALTA UTILITIES CORPORATION (CALGARY) AND OTHER PARTICIPANTS[1]

Whether carbon dioxide is a major cause of the "greenhouse effect" remains to be seen. In case it becomes necessary in the future to reduce the amount of carbon dioxide emitted to the atmosphere, a project was undertaken this year to review the published scientific literature on the disposal or use of carbon dioxide.

A study was subcontracted to Battelle Laboratories of Columbus Ohio to review current and evolving technologies capable of separating, disposing or using carbon dioxide, with particular emphasis on Alberta's needs and circumstances.

The study report provided a state-of-the-art review of approximately 30 potentially appropriate technologies and approaches, and included critical assessments of the most promising options. Essentially, the reviewed technologies were divided into four types: avoidance, capture, use and disposal.

Since most of the power plants and industrial boilers that will be operating in the year 2005 have already been built, it was believed the most appropriate approach would be to find a suitable technology that can be retrofitted to the existing equipment.

It was concluded that using methanolamine (MEA) flue gas scrubbing to capture gaseous carbon dioxide emissions is technically feasible, but unlikely because the recovery costs are very high. A better alternative would be to use the flue gas recycling combustion technology being developed at the Argonne National Laboratory in the U.S.A. This produces a flue gas that is approximately 95 per cent carbon dioxide, allowing economic recovery of the gas on small (less than 300 MW) power plants.

[1] Funding was provided by a consortium led by TransAlta Utilities Corporation. The other members were: NOVA Corporation of Alberta, Edmonton Power, Shell Canada Limited, Saskatchewan Energy and Mines, Energy, Mines and Resources Canada, Environment Canada, and the Alberta Office of Coal Research and Technology.

When new power plants are built, the study recommended that IGCC systems be used because they permit recovery of carbon dioxide in a manner that is more economic than any type of retrofitted technology. This is in addition to the higher efficiency of IGCC systems, resulting in the production of less carbon dioxide relative to conventional combustion processes.

Regardless of how the carbon dioxide is recovered, probably the best use for it in western Canada would be in enhanced oil recovery.

If carbon dioxide is produced in quantities well in excess of possible uses and must be disposed of, it was recommended that western Canada's substantial geological formations containing calcium or magnesium brines be considered as potential disposal sites. Reaction of carbon dioxide with these substances could produce stable carbonates capable of remaining safely underground for geological time.

***Publication***

Lipinsky, E.S. 1991. Final Report on R&D Status of Carbon Dioxide Separation, Disposal and Utilization Technologies. Battelle.

# Enhanced Oil Recovery

In 1985/86, the Office and several companies financed a study entitled Fuel Options for Enhanced Hydrocarbon Recovery. The investigation concluded that it was cost-effective for oil companies to use coal instead of natural gas to generate steam needed for enhanced recovery of heavy oil. The study also noted that to use coal successfully in heavy oil recovery schemes, a specially designed, pulverized coal-fired boiler was needed.

Subsequently, a Coal Use for Heavy Oil Recovery Technical Committee[1] was formed. It proposed a four-stage development program as the next step in using coal for heavy oil recovery. In the first stage of the program, two boiler manufacturers proposed designs for an innovative coal-fired steam generator. In the second stage, Combustion Engineering prepared an engineering design, which was described in earlier reports of the project Coal-Fired Steam Injection Boiler. Concurrently, the committee agreed to investigate the suitability of using the Low $NO_x/SO_x$ Burner (LNSB) system being developed by TransAlta Resources Investment Corporation. This led to two projects. One, Application of the LNS Burner to an Oil Field Steam Generator, was initiated and concluded previously. The other, LNSB Steam Generator Demonstration, continued this year.

Also included in this program were investigations of the merits of using slurry pipelining systems developed by Unocal Canada Limited to convey coal-condensate or coal-oil mixtures from Alberta coal mines to sites of heavy oil extraction operations.

Having achieved its objectives of developing and demonstrating the technology needed to use coal in place of natural gas for steam raising in heavy oil operations, the Committee was disbanded this year.

Progress thus far is described in the following Office publications: *Opportunities to Use Coal in Enhanced Oil Recovery*, and *Development of a Coal-Fired Boiler for Steam Injection in Heavy Oil Recovery*. In addition, some details about the Low $NO_x/SO_x$ Burner are included in the publication, *Development of Clean Coal Technologies for Alberta*. All three are available from the Alberta Energy/Forestry, Lands and Wildlife information centres.

[1] In addition to the Office, Committee members were: Esso Resources Canada Limited, Fording Coal Limited, Luscar Ltd., TransAlta Utilities Corporation, Alberta Power Limited, Shell Canada Limited, Unocal Canada Limited, Energy, Mines and Resources Canada, Alberta Oil Sands Technology and Research Authority, and other observers. Delta Projects Inc. provided co-ordination and promotional services to the Committee.

## LNS Burner Steam Generator Demonstration

TRANSALTA RESOURCES INVESTMENT CORPORATION AND ESSO RESOURCES CANADA LIMITED, CALGARY

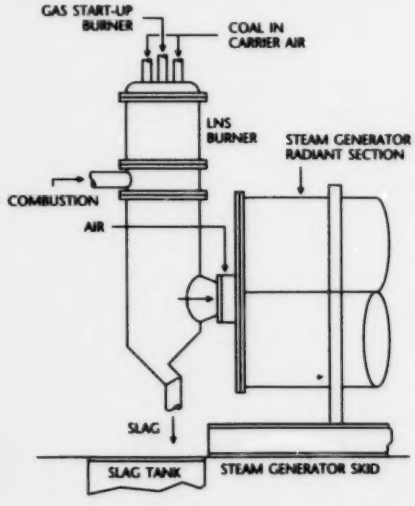
In 1988, a three-year project was initiated to demonstrate the LNS Burner at an Esso Resources Canada Limited heavy oil operation near Cold Lake.

The principal objectives of the project are to demonstrate:

- the ability to burn coal in an existing heavy oil recovery (HOR) steam generator using the LNS Burner. A standalone, 52.7 GJ/h steam generator has been built for this purpose;
- the capability of the LNS Burner to reduce $SO_2$ and $NO_x$ emissions while firing Alberta subbituminous coals at a commercial scale under regular operating conditions; and
- the reliability and durability of conventional, auxiliary systems operating with the burner and steam generator.

Project engineering began in October 1988, and plant construction was completed in June 1990, resulting in a LNS Burner being fitted to a coal-fired steam generator. The system is designed to provide 80 per cent quality steam at 15.5 MPa from formation waters produced along with bitumen as part of Esso's commercial project near Cold Lake.

**LNS Burner/Steam Generator Assembly**




The system is designed to use Highvale coal, which averages 0.2 per cent sulphur, and to produce emissions containing less than 129 ng/J (0.3 lb./million BTU) of sulphur dioxide. This is one-half the amount stipulated in the current Clean Air Act guideline. Also, nitrogen oxide emissions are expected to be lower than 86 ng/J (0.2 lb./million BTU), and particulate emissions should be lower than 43 ng/J (0.1 lb./million BTU). These are well below the requirements of current regulations.

Operation and demonstration of the facility are taking place in four stages:

- start up on natural gas;
- start up on coal;
- performance evaluation; and
- extended system demonstration.

All individual components, instruments and analysers were checked during test runs with natural gas, and operators had completed their training sessions by early July 1990. This concluded the natural gas start up phase.

Coal testing began during the second week of July. Although this phase was expected to last only one month, it had to be extended to eight months to resolve unanticipated technical problems.

As an example, plugging at a slag tap was particularly troublesome.

Eventually, a new, larger slag tap was designed and installed. This appeared to have overcome the plugging problem at year-end.

Thus far, coal testing has indicated that the performance goals of 0.3 and 0.2 lb./million BTU of sulphur dioxide and nitrogen oxides, respectively, are being met.

The performance evaluation and extended systems demonstration phases are planned for the remainder of 1991, and additional funds have been committed by the participants.

## Coal-Condensate Slurry Pipelining[1]

UNOCAL CANADA LIMITED, CALGARY

At the same time that steam production by coal combustion is being demonstrated as a viable technology for the extraction of heavy oil, it is also necessary to reduce the costs of transporting coal from Alberta mines to heavy oil extraction sites.

One potential method for reducing coal transportation costs involves the coal-oil slurry pipelining technology developed by Unocal Canada Limited to deliver coal to Ontario or the west coast. Most of these developments have been described in previous reports.

In a project initiated in 1989/90, a variation on the Unocal technology was developed. It takes advantage of the need by heavy oil producers for a hydrocarbon diluent called "condensate". This liquid is transported by pipeline to heavy oil production areas. Thus, it was decided that the coal-oil transportation technology might be adapted to make use of the condensate and the existing condensate pipelines to transport coal to the heavy oil producing areas. Involved was the development of technology required to prepare coal-condensate slurry, pipe it to a heavy oil field and separate it into its respective components.

From previous work on the Unocal slurry pipeline concept, it is known that certain cost advantages relative to rail haul are likely.

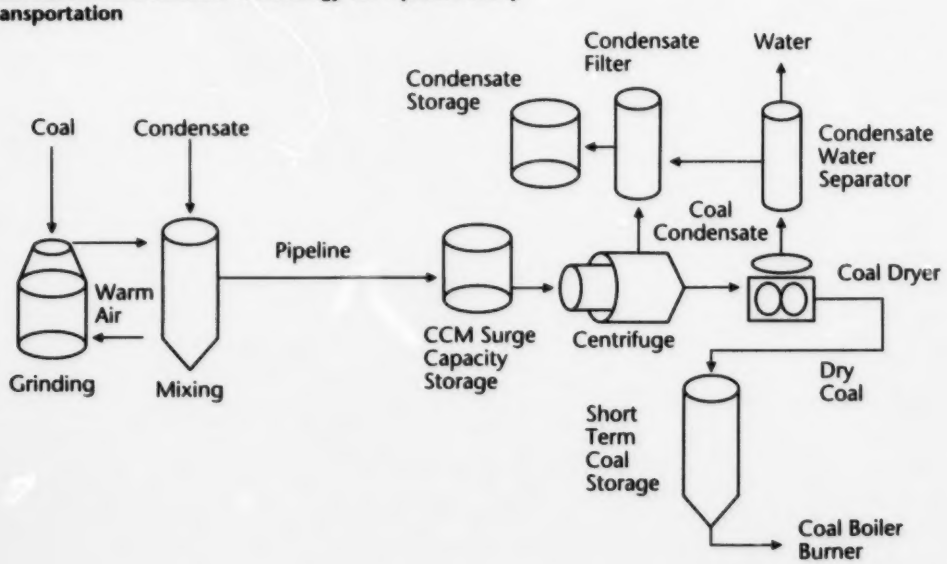
For example:

- central coal grinding facilities can be located at the mine site;
- the potential combination of a slurry pipeline and the TransAlta LNS Burner could reduce the need for excess drying equipment; and
- coal from various sources could be used because the costs associated with the haul distance from a mine to the user become less important when pipelines are used. Furthermore, the required pipelines already exist.

Thus far, it appears that transportation by slurry pipeline will cost less than by rail. When this cost reduction is combined with a potential rise in the cost of natural gas, the opportunities for using coal in place of natural gas are improved.

[1] Financial support for this project was provided by Unocal Canada Limited, Department of Western Economic Diversification and the Alberta Office of Coal Research and Technology.

**Coal-Condensate Mixture Technology for Pipeline Slurry Transportation**



To enhance this advantage, technology development was carried out on slurry preparation, piping and separation of the coal-condensate slurry. Also, negotiations were begun to obtain access to the LNS Burner being demonstrated near Cold Lake.

This work included the following:

- identifying coal preparation and cleaning requirements;
- developing design parameters for coal/condensate mixtures that can be separated;
- characterizing the transportation properties of coal/condensate slurries;
- developing a technology for efficient separation of coal and condensate; and
- analysing pipeline capacities.

As a result of this work, the performance of all major processing equipment needed to produce and separate coal/condensate slurries was verified. Pilot-scale data on the most critical equipment was acquired for an engineering cost study. This is a separate investigation and is reported under the project title Coal/Condensate Slurry Pipeline - Engineering/Cost Study.

***Publications***

Chambers, A.K., A. Turak, R. Zacharkiw, D. Ungarian and B. Croy. 1990. Vendor Equipment Testing for transCOM and Coal/Condensate Slurry Production and Separation. Prepared for Unocal Canada Limited. Alberta Research Council.

Frankiewicz, T.C., R.E. Miller, S.C. Hanson, G. Pangracs and G. Perry. 1990a. Coal/Condensate Slurry Phase I. transCOM Phase II. Project Report on Laboratory and Pilot-Scale Research and Development Volume I. Science and Technology Division, Union Oil Company of California.

Frankiewicz, T.C., R.E. Miller, S.C. Hanson, G. Pangracs and G. Perry. 1990b. Coal/Condensate Slurry Phase I. transCOM Phase II. Project Report on Laboratory and Pilot-Scale Research and Development Volume II, Parts 1, 2 and 3. Science and Technology Division, Union Oil Company of California.

## Coal-Condensate Slurry Pipeline - Engineering/Cost Study

UNOCAL CANADA LIMITED, CALGARY[1]

During 1990, Bantrel Inc. was subcontracted by Unocal Canada Limited to carry out an engineering and cost study of Unocal's coal slurry systems, with the principal objective of preparing capital and operating cost estimates for the following options:

- transportation of a coal-condensate slurry from the coal mines near Wabamun Lake to Cold Lake, using existing pipelines; and
- transportation of a coal-light crude oil slurry between the Obed Mountain mine and Sarnia, using existing pipelines.

The conceptual design and equipment for this evaluation were based directly on the test results from the Coal-Condensate Slurry Pipelining and transCOM Phase II projects.

For both options examined, modifications to the existing pipelines, pumping stations and intermediate storage facilities were excluded. Thus, the principal components of both systems were for slurry preparation and subsequent separation of either the coal-condensate or the coal-crude oil. Also, both commercial-scale systems were designed to deliver two million tonnes of coal a year.

Plus or minus 25 per cent estimates were prepared for capital and operating costs for both configurations. This information was provided to Unocal, but is currently regarded as confidential.

***Publication***

Bantrel Inc. 1990. Coal Oil Slurry Study.

[1] Financial support for this project was provided by Unocal Canada Limited, Department of Western Economic Diversification and the Alberta Office of Coal Research and Technology.

# Western Canadian Low-Sulphur Coal to Ontario Program

Since the mid-1980s, the potential social and economic benefits of using increased amounts of western Canadian coal in Ontario have been investigated and described by various federal/provincial task forces representing the federal government and the governments of Ontario and the western coal-producing provinces. The most recent of these groups, called the Action Committee on Western Canadian Low-Sulphur Coal to Ontario, comprises the Deputy Prime Minister and the premiers of British Columbia, Alberta, Saskatchewan and Ontario. In 1987, this committee created an Intergovernmental Secretariat which consulted with coal producers, transporters and users to develop possible technological, regulatory and policy options that could lower the delivered cost of western Canadian coal in Ontario.

In its November 1987 report to the Action Committee, the Secretariat identified 14 research and development initiatives within four broad categories that should be pursued. They are as follows:

- Mine Production Improvements;
- Coal Product Improvements;
- Transportation Improvements; and
- Fiscal and Regulatory Improvements.

While each of these initiatives will involve cooperation among the member governments and industry, the Alberta government has agreed to take the lead in implementing the following three initiatives:

- Underground Thick Seam Extraction Using the Room and Pillar System of Mining;
- Ash Reduction, Refuse Reprocessing and Fines Processing; and
- Coal-Oil Mixture Slurry Transportation Concept.

Some of these activities and those led by other governments or The Coal Association of Canada are directed by management committees comprising representatives of interested governments and industries.

The program includes studies of the impact of taxes and regulatory costs on coal transportation by railways and pipelines, and on coal producers.

### Thick Seam Extraction and Continuous Haulage Mining Demonstration

SMOKY RIVER COAL LIMITED, GRANDE CACHE

Considerable reserves of high-quality thermal and metallurgical coal are present in seams more than 3.7 m thick in western Canadian coalmines, but many of these seams are steeply inclined and difficult to mine using current extraction methods. Most mechanized coalmining machines cannot reach heights above 3.5 m, leaving large quantities of coal unmined.

Recent developments in machinery design and mining systems, however, suggest that seams up to 6 m thick can be mined successfully by consistently removing more of the coal that comprises the floor of the mined area. This could permit recovery rates that are up to 15 per cent higher than current rates. Furthermore, the current practice of using shuttle cars to transport mined coal from the active face to a distant conveyor causes a 21 per cent loss in the optimum operating time of the continuous miner while it waits for shuttle cars to deliver their loads and make the return trip.

Consequently, a project was initiated in 1989 at the Smoky River coalmine to evaluate new methods of mining coal at greater heights, and to assess a mobile roof support system to bolt the 6-m high roof in the underground mine. These were accompanied by the use of a mobile conveyor capable of continuously removing the mined coal. This conveyor, which is 183 m long and can negotiate 90° turns, is designed to transport 12 tonnes of coal a minute. It was anticipated that the mobile conveyor would be 30 per cent more productive than the shuttle-car system.

Also, a strata monitoring program was implemented to determine the effects, if any, of the higher roof heights on the behaviour of the coal seam and surrounding overburden.

Last year, a Fletcher dual head roof and side bolter was used successfully to support the roof and sides of extracted coal seams. The presence of sheared coal, however, prevented using the full height capabilities of the equipment. Heights of only 3.7 m to 4.3 m could be excavated safely.

Also, problems with the electrical and mechanical systems of the Kloeckner-Becorit mobile conveyor delayed its use for most of 1989. During the first half of 1990, the conveyor transported increasing quantities of coal, and on one occasion moved 800 tonnes in 4.5 hours. This represented a 35 per cent improvement over the use of shuttle cars.

During the second half of 1990, several problems with the mobile conveyor arose. Numerous electrical and mechanical breakdowns occurred, causing inconsistent performance, and the machine could not properly negotiate soft floors or gradients in the seam. Although the conveyor could travel in a straight line over level surfaces, it tended to move sideways in a snake-like fashion whenever an inclined portion was encountered in the floor. After consultation with the equipment manufacturer, it was decided to reduce the length of the mobile conveyor to 134 m.

At year-end, modifications were being made to the conveyor and a test was planned. The results of this test will help determine whether to extend or terminate the project.

The project was financed equally by Smoky River Coal Limited, the Department of Western Economic Diversification and the Alberta Office of Coal Research and Technology.

***Publications***

Associated Mining Consultants Limited. 1989. Geotechnical Monitoring Thick Seam Room-and-Pillar Demonstration Project. A report to Smoky River Coal Limited.

Kulach, J. 1989. Thick Seam Underground Mining Demonstration Project. Ground Control Monitoring and Instrumentation Plan. Smoky River Coal Limited.

Kulach, J. and H.H. Sandkuhler. 1990. Continuous Transport of Materials, Underground Flexible Conveyor System. CIM 92nd Annual General Meeting, Ottawa, Ontario.

Kulach, J. and H.H. Sandkuhler. 1989. Thick Seam Underground Mining Demonstration Project. CIM Conference, Calgary, Alberta.

## Air-Sparged Hydrocyclone

HYDRO PROCESSING & MINING LTD., CALGARY

As world coal markets become more competitive, the ability to clean the fine components (28 x 0 mesh) of western coals becomes more important, particularly when the tendency toward increased use of mechanized mining causes more coal fines to be produced.

One coal-cleaning method for fines which is showing promise relative to conventional flotation methods, uses a patented device called an Air-Sparged Hydrocyclone (ASH). It was developed at the University of Utah and is capable of recovering particles that are 1/20th the size of the smallest recoverable with conventional flotation methods. Also, the retention time in an ASH is only a few seconds, but it can be several minutes in a flotation device. Because an ASH is 1/100th the size of a flotation cell, both the capital and operating costs are claimed to be lower.

To demonstrate the effectiveness of using an ASH on western Canadian coals, 15-cm units were installed and operated at the Fording River and Smoky River coalmines during 1989/90. At the Fording River mine, some difficulty was encountered in operating the ASH consistently, and similar problems arose at Smoky River in controlling the device and keeping it operating in a stable mode. It appears that as many as seven operating variables affect the efficiency of the device, and computer control was deemed to be necessary. Nonetheless, the Smoky River trials showed that 70 per cent recovery of minus 28 mesh and 90 per cent recovery of minus 50 mesh material was possible. These results are comparable to those from a flotation system. Also, the ASH was easily retrofitted into an existing wash plant system.

At year-end, discussions were under way regarding the future of the project.

Financing was provided by Hydro Processing & Mining Ltd., the Department of Western Economic Diversification and the Alberta Office of Coal Research and Technology.

## Developing a Practical Model for the Compound Water Cyclone

CYCLONE ENGINEERING SALES LTD., EDMONTON

Although compound water cyclones (CWC) (also known as water-only or automedium cyclones) are commonly used in coal preparation plants, it has been found that maintaining optimum performance of these devices is difficult because changes occur in the properties of the coal being cleaned.

The most accurate method for determining performance of a CWC is to conduct a washability analysis on the feed coal and reject material. This is both time consuming and expensive, however. Also, being neither instantaneous nor continuous, the analysis results do not accurately reflect the performance, other than for the brief period during which samples were collected from the circuit.

It is essential, therefore, to have some convenient method for predicting the performance of CWCs. For this reason, a mathematical model of an automedium cyclone was developed at the University of Alberta in the mid-1980s. It was found to be a potentially useful process control method. The laboratory and pilot plant investigations that led to this model, however, used 20-cm diameter cyclones, whereas most of the CWCs used in coal preparation plants are 30 cm in diameter.

Thus, the objective of a project initiated in 1990/91 was to develop the automedium model further so that it would apply to 30-cm and 38-cm diameter units. This would be accomplished by determining how sensitive the current model is to changes in the geometry and operating conditions of water-only cyclones in operating plants, and by measuring the ash content and yields of coals cleaned in the large units.

A literature review was carried out to update existing information about mathematical modelling of these types of cyclones, and then a sampling program was begun at the coal preparation plants of the Gregg River and Byron Creek coalmines. In addition, bulk samples from the Gregg River mine were sent to CANMET for pilot-plant testing, using a 30-cm diameter CWC having a hydraulic lift vortex finder. Subsequent analysis of the data revealed some inconsistencies in the yield calculations. While there was evidence from the CANMET studies that the 20-cm diameter model is applicable to the 30-cm diameter CWC, and it can predict the performance with acceptable accuracy, much of the data were not suitable for development of a model. At year-end, the coal industry participants withdrew their support.

The project received financial support from Esso Resources Canada Limited, Gregg River Resources Ltd., Cyclone Engineering Sales Ltd., the Department of Western Economic Diversification, and the Alberta Office of Coal Research and Technology.

## Tailings Reclamation

LUSCAR STERCO (1977) LTD., (EDSON) AND LUSCAR LTD. (OBED)

All coal preparation plants generate coal refuse known as tailings. Depending on the type of coal being mined, as well as the preparation plant yield and the amount of clay present in the tailings, the disposal of tailings into holding ponds can represent a significant portion of preparation plant operating costs.

Various methods for dewatering slurries containing tailings have been tried, including mechanical dewatering using filter presses. In this project, however, an alternative method is being tried. It involves dewatering an existing tailings pond and experimenting with various methods for stabilizing and reclaiming it. If this is practical, slurry dewatering might not be necessary and tailings ponds can be converted to a more useful purpose than for waste storage.

For this concept to be successful in practice, it is necessary to determine how much topsoil and subsoil are needed to reclaim the tailings pond in an environmentally sustainable manner.

Initially, greenhouse tests were carried out at the Alberta Research Council to identify plant species capable of growth on tailings ponds at the Coal Valley and Obed Mountain mines. These botanical tests were carried out on tailings alone, soil alone, soil over tailings, and a 1:1 mixture of soil and tailings.

Then, a 3-acre parcel of a drained tailings pond at the Coal Valley mine was prepared for seeding. The plot was divided into four sections: tailings only; tailings plus 15-cm or 30-cm soil caps; and a 15-cm soil cap above a 105-cm layer of spoil material that was placed over the tailings. These sections were seeded with mixtures of reed canary grass, alfalfa, timothy, clover and redtop.

Meanwhile, geotechnical assessment of the site began. This work was carried out by Thurber Consultants Ltd. and included installation of piezometers and settlement plates, as well as performing vane shear and cone penetrometer tests.

More than one year after the seed mixtures were sown, plant tissue and growth analyses were carried out. Thus far, the biological tests have shown that the tailings material is biologically non-toxic and is capable of supporting plant growth under most conditions. Also, plant growth was improved somewhat in the test sections that used a soil cap. The extent of this improvement was being investigated further at year-end.

The final assessment and more geotechnical monitoring will be carried out next year.

Financial support for this project is being provided by Luscar Sterco (1977) Ltd., Luscar Ltd., the Department of Western Economic Diversification, and the Alberta Office of Coal Research and Technology.

## Thermal Drying of Western Canadian Low-Rank Coals

TRANSALTA UTILITIES CORPORATION, CALGARY

Lignite and subbituminous coals from western Canada contain significant quantities of moisture. This reduces their heating value and lowers their competitive position relative to coals from other sources.

It has been proposed that removal of this moisture by thermal drying could upgrade these low-rank coals, thereby allowing their use in thermal power plants designed for higher rank coal. Also, removal of moisture should reduce the costs to transport these coals to markets in Ontario. The disadvantage of thermal drying is that dried coals tend to be susceptible to spontaneous combustion.

Thus, a subbituminous B coal from the Highvale mine, a high-volatile coal from the Obed mine, and a lignite from the Costello mine in Saskatchewan were tested at the CANMET laboratories in Devon and the Energy Research Unit of the University of Regina. The objective was to prepare a database of thermal drying results to help determine the process limits and provide some indication of the economics of this approach to moisture removal.

Each coal was treated thermally at temperatures that varied from 200°to 400°C in three process media: nitrogen, steam and simulated products of combustion. Detailed analyses of each coal were carried out. Changes in coal properties as a function of thermal treatment temperature and process gas were interpreted in terms of changes in coal rank and the likelihood of spontaneous combustion.

It was found that the heating value of all three coals increased with temperature in the presence of all the gases. It was recommended that these coals should be heated above 300°C and below 400° to achieve a significant increase in heating value.

There was no loss of mineral matter or any measurable change in the mineral composition, but oxygen, oxygen-containing groups and volatile aliphatic carbon were all reduced.

The results regarding the susceptibility to spontaneous combustion were erratic, but it did appear that steam was marginally better at reducing this tendency.

This project was funded by TransAlta Utilities Corporation, Manalta Coal Ltd., Esso Resources Canada Limited, the Department of Western Economic Diversification, and the governments of Alberta, Ontario and Saskatchewan. Alberta's contribution was administered by the Office of Coal Research and Technology.

***Publication***

CANMET (Devon) and Energy Research Unit, University of Regina. 1991. Fundamentals of Low Rank Coal Thermal Upgrading via Evaporative Drying.

## Feasibility Study - IGCC

THE COAL ASSOCIATION OF CANADA, CALGARY

The Coal Association of Canada is the lead agency in a project funded jointly by several governments and industry[1]. The objective is to undertake a feasibility study of an Integrated Gasification Combined Cycle (IGCC) power plant. The technology will differ from other IGCC technologies in its potential ability to recover carbon dioxide.

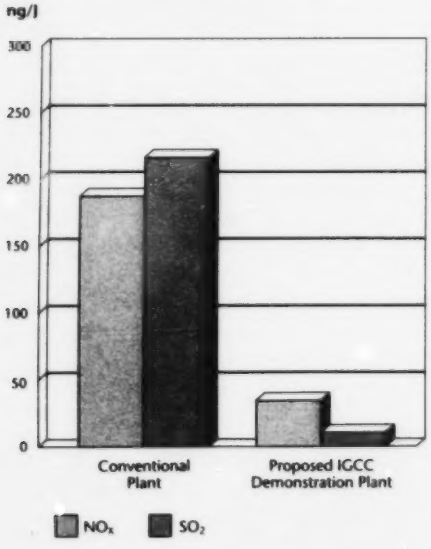
The feasibility study has been subcontracted to Bechtel Canada Inc., and a preliminary environmental study is being carried out by Beak Associates Consulting Ltd.

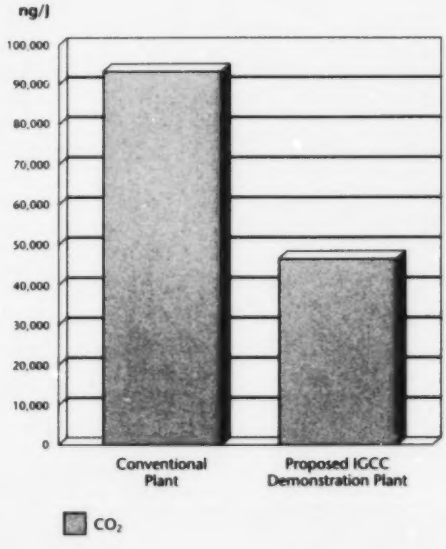
A decision has been made to use Shell gasifier technology capable of using 2 740 tonnes of coal a year and generating up to 250 MW of electrical power. If built, the plant would be the world's largest IGCC operation.

Meanwhile, four likely sites for a plant are being considered in the study. They are: the Keephills plant of TransAlta Utilities; Edmonton Power's Genesee plant; Saskatchewan Power's Shand II plant, and a new mine and power plant complex near Brooks, Alberta, that has been proposed by Fording Coal Limited.

[1] The Coal Association of Canada members making financial contributions to the project include 13 utility and coal companies, as well as the Canadian Electrical Association. The governments of British Columbia, Alberta, Saskatchewan, Ontario and Canada are providing two-thirds of the funding under the Western Canadian Low-Sulphur Coal to Ontario Program.

**Reduction of Atmospheric Emissions**



# Project Expenditures

## Table I: Funding Contributions to Approved Projects by Year ($)

| PROJECT TITLE | 1977/78 | 1978/79 | 1979/80 | 1980/81 | 1981/82 | 1982/83 | 1983/84 | 1984/85 | 1985/86 | 1986/87 | 1987/88 | 1988/89 | 1989/90 | 1990/91 | 1991/91 (Projected) | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A/CERRF - FUNDED PROJECTS** | | | | | | | | | | | | | | | | |
| **A/CERRF - COAL RESEARCH** | | | | | | | | | | | | | | | | |
| **Resource Evaluation** | | | | | | | | | | | | | | | | |
| Creep Characteristics of Coal | - | - | - | - | - | - | 14 439 | 2 020 | - | - | - | - | - | - | - | 16 459 |
| Reflective Seismic Investigation of Western Canadian Coalfields | - | - | - | - | - | - | 3 564 | - | - | - | - | - | - | - | - | 3 564 |
| VLF Geophysical Methods in Coal Exploration | - | - | - | - | - | - | - | 4 426 | 10 420 | - | - | - | - | - | - | 14 846 |
| Geophysical Instrumentation | - | - | - | - | - | - | - | - | 69 470 | - | - | - | - | - | - | 69 470 |
| Geotechnical Properties of Overburden | - | - | - | - | - | - | - | - | 71 501 | - | - | - | - | - | - | 71 501 |
| Surface Geophysical Coal Exploration | - | - | - | - | - | - | - | 96 915 | 111 996 | 124 557 | - | - | - | - | - | 333 468 |
| 3-D Structural Geometry | - | - | - | - | - | - | - | - | 22 873 | 30 127 | - | - | - | - | - | 53 000 |
| In-Seam Coal Characterization | - | - | - | - | - | - | - | - | - | 92 718 | 144 106 | - | - | - | - | 236 824 |
| Seismic Modelling of Shallow Coalfields | - | - | - | - | - | - | - | - | - | 24 723 | 7 720 | 37 096 | 159 | - | - | 69 698 |
| Downhole Geophysical Characterization of Overburden | - | - | - | - | - | - | - | - | - | 30 667 | 44 099 | 104 500 | - | - | - | 179 266 |
| Surface Geophysical Techniques for Foothills and Mountain Coalfield Exploration | - | - | - | - | - | - | - | - | - | - | - | 73 835 | 47 094 | 146 842 | - | 267 771 |
| Coal Bed Methane: An Alberta Opportunity | - | - | - | - | - | - | - | - | - | - | - | - | - | 40 000 | - | 40 000 |
| **SUBTOTAL: Resource Evaluation** | **0** | **0** | **0** | **0** | **0** | **0** | **18 003** | **103 361** | **286 280** | **302 792** | **195 925** | **215 431** | **47 253** | **186 842** | **0** | **1 288 887** |
| **Mining** | | | | | | | | | | | | | | | | |
| Support Design for Underground Cavities in Weak Rock | - | - | - | - | - | - | 1 350 | - | - | - | - | - | - | - | - | 1 350 |
| Coal Mining Research | 14 682 | 67 595 | 115 347 | 181 640 | 225 662 | 296 129 | 358 220 | 278 838 | 417 439 | - | - | - | - | - | - | 1 955 562 |
| Coal Mining in 2035 | - | - | - | - | - | - | - | - | 78 682 | - | - | - | - | - | - | 78 682 |
| Triaxial Test Development | - | - | - | - | - | - | - | - | - | 103 503 | - | - | - | - | - | 103 503 |
| Ground Movements in Coal Mines | - | - | - | - | - | - | - | - | 11 469 | 14 031 | - | - | - | - | - | 25 500 |
| Mining 2035 Workshop | - | - | - | - | - | - | - | - | - | 25 226 | - | - | - | - | - | 25 226 |
| Robotics for Mine Control | - | - | - | - | - | - | - | - | - | 96 178 | - | - | - | - | - | 96 178 |
| Non-Cable Vehicle Guidance | - | - | - | - | - | - | - | - | - | - | 133 455 | - | - | - | - | 133 455 |
| Lasers in Coal Mining | - | - | - | - | - | - | - | - | - | - | 50 954 | - | - | - | - | 50 954 |
| Geostatistics | - | - | - | - | - | - | - | - | - | - | 40 958 | - | - | - | - | 40 958 |
| Footwall Anchoring | - | - | - | - | - | - | - | - | - | 81 246 | 57 853 | - | - | - | - | 139 099 |
| Time-Dependent Behaviour of Coal Measure Rocks | - | - | - | - | - | - | - | - | - | 15 288 | 19 745 | 4 967 | - | - | - | 40 000 |
| Deformation and Progressive Failure of Open-Pit Highwalls | - | - | - | - | - | - | - | - | - | 44 | 71 934 | 12 724 | - | - | - | 84 702 |
| Automated Machine Control for Optimized Mining (AAMCOM) | - | - | - | - | - | - | - | - | - | - | - | 197 222 | - | - | - | 197 222 |
| Dragline Operations Monitor | - | - | - | - | - | - | - | - | - | - | - | 40 225 | - | - | - | 40 225 |
| **SUBTOTAL: Mining** | **14 682** | **67 595** | **115 347** | **181 640** | **225 662** | **296 129** | **359 570** | **278 838** | **607 580** | **335 516** | **374 099** | **255 138** | **0** | **0** | **0** | **3 912 916** |

| PROJECT TITLE | 1977/78 | 1978/79 | 1979/80 | 1980/81 | 1981/82 | 1982/83 | 1983/84 | 1984/85 | 1985/86 | 1986/87 | 1987/88 | 1988/89 | 1989/90 | 1990/91 | 1991/91 (Projected) | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Preparation and Upgrading** | | | | | | | | | | | | | | | | |
| Beneficiation of Coal by Agglomeration in Pipelines | - | - | - | | | | 22 220 | - | - | - | - | - | - | - | - | 22 220 |
| Coal Preparation Research | 39 845 | 183 315 | 312 815 | 492 675 | 612 060 | 803 189 | 835 845 | 1 188 731 | 224 014 | - | - | - | - | - | - | 4 882 489 |
| Coal Comminution | - | - | - | - | - | - | - | - | - | 54 466 | - | - | - | - | - | 54 466 |
| Numerical Analysis of Process Yield Losses | - | - | - | - | - | - | - | - | 56 000 | 19 795 | - | - | - | - | - | 75 795 |
| Advanced Processes for Low-Rank Coal | - | - | - | - | - | - | - | - | - | 79 392 | - | - | - | - | - | 79 392 |
| Properties of Thermally Dried Coals | - | - | - | - | - | - | - | - | 99 459 | 45 000 | - | - | - | - | - | 144 459 |
| Stabilization of Dried Coal | - | - | - | - | - | - | - | - | - | 37 423 | - | - | - | - | - | 37 423 |
| Agglomeration of Low-Rank Alberta Thermal Coals | - | - | - | - | - | - | 136 754 | - | - | - | - | (5 969) | - | - | - | 130 785 |
| Agglomeration for Beneficiation | - | - | - | - | - | - | - | - | 18 444 | 31 328 | - | - | - | - | - | 49 772 |
| Preparation and Upgrading Assistance to AOCRT | - | - | - | - | - | - | - | - | - | 705 | 41 295 | - | - | - | - | 42 000 |
| Moisture and Ash On-Stream Analyser | - | - | - | - | - | - | - | - | - | - | 26 553 | - | - | - | - | 26 553 |
| Recovery of Coal from Tailings | - | - | - | - | - | - | - | - | - | - | 82 231 | - | - | - | - | 82 231 |
| Fine Coal Technical Assistance | - | - | - | - | - | - | - | - | - | - | 2 308 | - | - | - | - | 2 308 |
| Froth Flotation Study at Coal Valley | - | - | - | - | - | - | - | - | - | - | 29 237 | - | - | - | - | 29 237 |
| Washery Optimization | - | - | - | - | - | - | - | - | - | 93 876 | 127 102 | - | - | - | - | 220 978 |
| Coal Beneficiation Process | - | - | - | - | - | - | - | 68 546 | 153 440 | 595 072 | 66 920 | 23 461 | - | - | - | 907 439 |
| Agglomeration of Coking Coal | - | - | - | - | - | - | - | - | - | - | 90 000 | - | - | - | - | 90 000 |
| Westcoal Separator Phase II | - | - | - | - | - | - | - | - | - | - | - | 24 898 | - | - | - | 24 898 |
| Coal Production Program Planning | - | - | - | - | - | - | - | - | - | - | - | 36 750 | 6 484 | - | - | 43 234 |
| Electrocoagulation | - | - | - | - | - | - | - | - | - | - | - | 15 046 | - | 33 333 | - | 48 379 |
| Coal Agglomeration Process Development | - | - | - | - | - | - | - | - | - | - | 35 000 | 35 000 | 17 500 | 38 500 | - | 126 000 |
| Particle Distribution in Slurry Flow Through Tees and Manifolds | - | - | - | - | - | - | - | - | - | - | - | 53 222 | 43 570 | 16 178 | - | 112 970 |
| Coal/Oil Upgrader | - | - | - | - | - | - | - | - | - | - | - | - | - | 93 500 | - | 93 500 |
| **SUBTOTAL: Preparation and Upgrading** | **39 845** | **183 315** | **312 815** | **492 675** | **612 060** | **803 189** | **994 819** | **1 257 277** | **581 357** | **967 057** | **508 846** | **182 488** | **67 554** | **181 511** | **0** | **7 126 329** |
| **Combustion** | | | | | | | | | | | | | | | | |
| Combustion of Agglomerated Coal | - | - | - | - | - | - | - | 2 061 | 22 950 | 8 325 | - | - | - | - | - | 33 336 |
| Combustion Process Research | - | - | - | - | - | - | - | - | 21 814 | 128 401 | - | - | - | - | - | 150 215 |
| Combustion Characteristics of Alberta Coals | - | - | - | - | - | - | - | - | 83 066 | 105 904 | - | - | - | - | - | 188 970 |
| Combustibility of Agglomerates | - | - | - | - | - | - | - | - | - | 14 156 | - | - | - | - | - | 14 156 |
| Combustion Program Planning | - | - | - | - | - | - | - | - | 31 042 | 27 562 | 18 000 | - | - | - | - | 76 604 |
| Influence of Porosity on Combustion | - | - | - | - | - | - | - | - | - | - | 84 000 | - | - | - | - | 84 000 |
| Causes of Spontaneous Combustion of Western Canadian Coals | - | - | - | - | - | - | - | - | - | 52 040 | 46 396 | 705 | - | - | - | 99 141 |
| Combustibility of Upgraded Alberta Coals | - | - | - | - | - | - | - | - | - | - | 115 000 | - | - | - | - | 115 000 |
| Evaluation of Blending on Combustibility | - | - | - | - | - | - | - | - | - | - | 36 000 | - | - | - | - | 36 000 |
| Prediction of Coal Combustibility | - | - | - | - | - | - | - | - | 83 359 | 56 463 | 7 594 | - | - | - | - | 147 416 |
| Combustion Properties of Alberta Coals and Chars | - | - | - | - | - | - | - | - | - | - | - | 150 000 | - | - | - | 150 000 |

| PROJECT TITLE | 1977/78 | 1978/79 | 1979/80 | 1980/81 | 1981/82 | 1982/83 | 1983/84 | 1984/85 | 1985/86 | 1986/87 | 1987/88 | 1988/89 | 1989/90 | 1990/91 | 1991/91 (Projected) | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spontaneous Combustion of Thermally Treated Coals | - | - | - | - | - | - | - | - | - | - | - | 25 503 | - | - | - | 25 503 |
| International Energy Agency Basic Coal Combustion Science | - | - | - | - | - | - | - | - | 101 619 | 184 708 | 146 368 | 32 869 | - | - | - | 465 564 |
| A Thermodynamic Model for Spontaneous Combustion of Coal | - | - | - | - | - | - | - | - | - | - | - | 54 567 | 40 918 | - | - | 95 485 |
| Travel Grant to Study Sources of Ash in Controlled Conditions at IJmuiden | - | - | - | - | - | - | - | - | - | - | - | - | 5 231 | 3 044 | - | 8 275 |
| Program Extension to IEA Annex II Basic Coal Combustion Science | - | - | - | - | - | - | - | - | - | - | - | - | 94 640 | 102 383 | 210 944 | 407 967 |
| Coal Utilization Program Planning | - | - | - | - | - | - | - | - | - | - | - | 38 808 | 39 227 | 40 519 | 40 000 | 158 554 |
| Ash Properties of Alberta Coals | - | - | - | - | - | - | - | - | - | - | - | - | 49 962 | 148 638 | - | 198 600 |
| **SUBTOTAL Combustion** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **2 881** | **343 958** | **577 558** | **453 368** | **382 452** | **229 978** | **294 884** | **250 944** | **2 464 788** |
| **Liquefaction/Co-processing** | | | | | | | | | | | | | | | | |
| Coal Liquefaction Study | - | - | - | 151 864 | - | - | - | - | - | - | - | - | - | - | - | 151 864 |
| Coal Liquefaction Feasibility Study | - | - | - | - | - | - | - | 90 553 | - | - | - | - | - | - | - | 90 553 |
| PYROSOL Process Review | - | - | - | - | - | - | - | - | 7 006 | - | - | - | - | - | - | 7 006 |
| Liquefaction Process Improvement | - | - | - | - | - | - | - | - | 43 114 | 7 945 | - | - | - | - | - | 51 059 |
| ENR/ARC Coal Conversion Research | 2 055 | - | 37 412 | 1 182 372 | 3 135 406 | 4 158 527 | 3 034 865 | 2 240 729 | 550 983 | - | - | - | - | - | - | 14 342 349 |
| New Liquefaction Processes | - | - | - | - | - | - | - | - | 26 785 | 204 164 | - | - | - | - | - | 230 949 |
| Preliminary Economic Evaluation of a Multistage Coal/Heavy Oil Co-processing Concept and Development of a Simple Process Evaluation | - | - | - | - | - | - | - | - | 22 053 | 55 738 | - | - | - | - | - | 77 791 |
| Isotopic Analysis of Co-processing Schemes | - | - | - | - | - | - | - | - | 22 082 | 51 918 | - | - | - | - | - | 74 000 |
| Secondary Upgrading | - | - | - | - | - | - | - | - | - | - | 182 671 | 329 | - | - | - | 183 000 |
| Functional Group Analysis of Coal Liquids | - | - | - | - | - | - | - | - | 30 515 | 49 793 | 10 692 | - | - | - | - | 91 000 |
| Chemistry of Coal Liquefaction | - | - | - | - | - | - | - | - | 72 410 | 132 822 | 303 672 | 5 753 | - | - | - | 514 657 |
| Secondary Upgrading of Co-processing Products | - | - | - | - | - | - | - | - | - | - | - | 172 000 | - | - | - | 172 000 |
| Supercritical Gas Extraction of Coal | - | - | - | - | - | - | - | - | - | 27 588 | 45 617 | 9 071 | - | - | - | 82 276 |
| Liquefaction of Coal with Natural Gas | - | - | - | - | - | - | - | - | - | - | 29 404 | 6 346 | - | - | - | 35 750 |
| Hydroprocessing of Coal-Derived Liquids | - | - | - | - | - | - | - | - | - | 15 607 | 46 209 | 24 205 | 19 379 | - | - | 105 400 |
| Isotopic Studies of Coal/Bitumen Co-processing Schemes | - | - | - | - | - | - | - | - | - | - | 77 784 | 43 508 | (586) | - | - | 120 726 |
| Molecular Interactions Between Heavy Oil and Coal Species During Co-processing | - | - | - | - | - | - | - | - | - | - | - | 48 464 | 54 813 | 3 123 | - | 106 400 |
| Product and Process Characterization | - | - | - | - | - | - | - | - | - | - | - | 218 156 | 86 864 | 71 706 | - | 376 726 |
| Co-processing Process Development | - | - | - | - | - | - | - | - | - | 2 282 650 | 803 481 | 630 249 | 643 763 | 257 159 | - | 4 417 282 |
| Combined Processing of Coal, Heavy Oil and Natural Gas | - | - | - | - | - | - | - | - | - | - | - | - | 18 783 | 41 217 | - | 60 000 |
| Specialty Chemicals from Coal-Derived Liquids | - | - | - | - | - | - | - | - | - | - | - | - | 79 900 | 129 544 | - | 209 444 |
| Process Development for Carbon Fibres from Coal-Derived Liquids | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 100 000 | 100 000 |
| Co-processing of Coal with Molten Halide Catalysts | - | - | - | - | - | - | - | - | - | - | - | - | 40 000 | 30 000 | - | 70 000 |

| PROJECT TITLE | 1977/78 | 1978/79 | 1979/80 | 1980/81 | 1981/82 | 1982/83 | 1983/84 | 1984/85 | 1985/86 | 1986/87 | 1987/88 | 1988/89 | 1989/90 | 1990/91 | 1991/91 (Projected) | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Co-processing of Coal and Heavy Oil in Alberta, Phase II | - | - | - | - | - | - | - | - | - | - | - | - | - | 50 000 | - | 50 000 |
| Coal/Oil Co-processing Using a Counterflow Reactor | - | - | - | - | - | - | - | - | - | - | - | - | - | 296 369 | - | 296 369 |
| **SUBTOTAL: Liquefaction/Co-processing** | **2 855** | **0** | **37 412** | **1 334 236** | **3 135 486** | **4 158 527** | **3 834 865** | **2 331 282** | **774 948** | **2 828 225** | **1 299 510** | **[illegible]** | **942 936** | **879 118** | **188 000** | **22 016 881** |
| **Gasification** | | | | | | | | | | | | | | | | |
| Gasification of Western Canadian Coals | - | - | - | - | - | - | - | - | - | 38 500 | - | - | - | - | - | 38 500 |
| Fluidized Bed Gasification of Highvale Coal | - | - | - | - | - | - | - | - | - | - | 64 201 | - | - | - | - | 64 201 |
| Gasification Process Research | - | - | - | - | - | - | - | - | - | 12 207 | 72 154 | (401) | - | - | - | 83 960 |
| Gasification Properties of Alberta Coals | - | - | - | - | - | - | - | - | - | 34 957 | 130 000 | - | - | - | - | 164 957 |
| Gasification Laboratory Facilities | - | - | - | - | - | - | - | - | - | - | 160 000 | - | - | - | - | 160 000 |
| Corrosion in Gasification Systems | - | - | - | - | - | - | - | - | - | 50 871 | - | 460 | - | - | - | 51 331 |
| Gasification Characteristics of Alberta Coals | - | - | - | - | - | - | - | - | - | 5 466 | 179 850 | 59 | - | - | - | 185 375 |
| Devolatilization Properties of Alberta Coals | - | - | - | - | - | - | - | - | - | - | - | 150 000 | 28 530 | - | - | 178 530 |
| IGCC Utility Applications | - | - | - | - | - | - | - | - | - | - | - | - | 25 000 | - | - | 25 000 |
| Canada/Japan Collaboration In Coal Gasification Research | - | - | - | - | - | - | - | - | - | - | - | - | - | 38 664 | 25 000 | 63 664 |
| Gasification Properties of Alberta Coals | - | - | - | - | - | - | - | - | - | - | - | 190 000 | 154 000 | 208 800 | - | 552 800 |
| **SUBTOTAL: Gasification** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **142 001** | **606 205** | **340 118** | **207 530** | **247 464** | **25 000** | **1 568 318** |
| **Transportation** | | | | | | | | | | | | | | | | |
| Coal Slurry Pipeline Research | - | - | - | - | - | - | 114 903 | 150 333 | 22 717 | - | - | - | - | - | - | 287 953 |
| Coal Market Access Model | - | - | - | - | - | - | - | - | - | - | 69 846 | 4 125 | - | - | - | 73 971 |
| Coal-Oil Slurry Pipelining | - | - | - | - | - | - | - | - | - | - | 204 331 | 455 578 | - | - | - | 659 909 |
| Coal Slurry Technology | - | - | - | - | - | - | - | - | - | - | 25 576 | 22 411 | 173 566 | 62 671 | - | 284 224 |
| **SUBTOTAL: Transportation** | **0** | **0** | **0** | **0** | **0** | **0** | **114 903** | **150 333** | **22 717** | **0** | **299 753** | **482 114** | **173 566** | **62 671** | **0** | **1 306 057** |
| **Environment** | | | | | | | | | | | | | | | | |
| Low $NO_x$/$SO_x$ Burner | - | - | - | - | - | - | - | - | - | 50 028 | - | - | - | - | - | 50 028 |
| Coal Conversion Waste-Water Treatment | - | - | - | - | - | - | - | - | 17 305 | 38 577 | 8 118 | - | - | - | - | 64 000 |
| Sorbent Injection Study | - | - | - | - | - | - | - | - | - | - | - | 15 000 | - | - | - | 15 000 |
| A State-of-the-art Review on $CO_2$ Separation/Disposal Technologies | - | - | - | - | - | - | - | - | - | - | - | - | - | 12 500 | - | 12 500 |
| Gypsum as an Alternate Flocculent in the Treatment of Coal Mine Effluent Water | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 25 240 | 25 240 |
| **SUBTOTAL: Environment** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **17 305** | **88 605** | **8 118** | **15 000** | **0** | **12 500** | **25 240** | **166 768** |
| **Markets** | | | | | | | | | | | | | | | | |
| Conversion from Oil to Coal-Water Fuels | - | - | - | - | - | - | - | - | 26 093 | 9 283 | - | 430 | - | - | - | 35 806 |
| Production of Activated Carbon | - | - | - | - | - | - | - | - | - | - | - | 759 | - | - | - | 759 |
| Activated Carbon from Coal | - | - | - | - | - | - | - | - | - | 31 738 | 57 997 | 10 265 | - | - | - | 100 000 |
| **SUBTOTAL: Markets** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **26 093** | **41 021** | **57 997** | **11 454** | **0** | **0** | **0** | **136 565** |

| PROJECT TITLE | 1977/78 | 1978/79 | 1979/80 | 1980/81 | 1981/82 | 1982/83 | 1983/84 | 1984/85 | 1985/86 | 1986/87 | 1987/88 | 1988/89 | 1989/90 | 1990/91 | 1991/91 (Projected) | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Enhanced Oil Recovery** | | | | | | | | | | | | | | | | |
| Fuel Options for Enhanced Oil Recovery | - | - | - | - | - | - | - | - | 15 000 | - | - | - | - | - | - | 15 000 |
| Coal Use in Enhanced Oil Recovery | - | - | - | - | - | - | - | - | - | 17 995 | 13 777 | - | - | - | - | 31 772 |
| Coal-Fired Steam Injection Boiler | - | - | - | - | - | - | - | - | - | - | 28 619 | 110 205 | - | - | - | 138 824 |
| Application of the LNS Burner to an Oil Field Steam Generator | - | - | - | - | - | - | - | - | - | - | - | 22 460 | - | - | - | 22 460 |
| Economics of Coal Use for Heavy Oil Recovery | - | - | - | - | - | - | - | - | - | - | - | - | 50 000 | - | - | 50 000 |
| Coal/Condensate Slurry Pipelining | - | - | - | - | - | - | - | - | - | - | - | - | 251 603 | 80 740 | - | 332 343 |
| LNS Burner Steam Generator Demonstration | - | - | - | - | - | - | - | - | - | - | - | 292 266 | 1 964 000 | 506 600 | 300 000 | 3 062 866 |
| Coal/Condensate Slurry Pipeline Engineering Cost Study | - | - | - | - | - | - | - | - | - | - | - | - | - | 25 311 | - | 25 311 |
| **SUBTOTAL: Enhanced Oil Recovery** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **15 000** | **17 995** | **42 396** | **424 931** | **2 265 603** | **612 651** | **300 000** | **3 678 576** |
| **Other** | | | | | | | | | | | | | | | | |
| Coal Technology Information Center | - | - | - | - | - | 143 753 | 114 830 | 123 537 | 189 000 | - | - | - | - | - | - | 571 120 |
| CTIC Review | - | - | - | - | - | - | - | - | 16 997 | - | - | - | - | - | - | 16 997 |
| Data Gathering for Research Planning | - | - | - | - | - | - | - | - | 10 784 | 41 212 | - | - | - | - | - | 51 996 |
| Electrolysis of Coal Slurries | - | - | - | - | - | - | - | - | 26 655 | 65 588 | 20 757 | - | - | - | - | 113 000 |
| Sulphur Isotope Studies of Coal | - | - | - | - | - | - | - | - | - | - | 25 119 | 38 081 | - | - | - | 63 200 |
| Electrolysis of Coal Slurries II | - | - | - | - | - | - | - | - | - | - | - | 48 497 | 11 503 | - | - | 60 000 |
| Distributed Chemical and Physical Properties of Coal | - | - | - | - | - | - | - | - | - | - | 8 973 | 30 450 | 12 538 | - | - | 51 961 |
| Magnetic and Electric Properties of Alberta Coals | - | - | - | - | - | - | - | - | - | - | 40 397 | 69 053 | - | - | - | 109 450 |
| Distribution of Oxygen Forms in Western Canadian Low-Rank Coals | - | - | - | - | - | - | - | - | - | - | - | 21 068 | 18 932 | - | - | 40 000 |
| **SUBTOTAL: Other** | **0** | **0** | **0** | **0** | **0** | **143 753** | **114 830** | **123 537** | **243 436** | **106 800** | **95 246** | **207 149** | **42 973** | **0** | **0** | **1 077 724** |
| **SUBTOTAL: A/CERRF - Coal Research** | **86 882** | **258 910** | **485 574** | **2 809 551** | **3 973 128** | **5 481 580** | **4 636 000** | **4 246 600** | **2 788 588** | **5 287 571** | **3 934 853** | **3 584 276** | **3 977 383** | **2 477 341** | **791 184** | **43 918 488** |
| **A/CERRF - Alberta Universities Program** | | | | | | | | | | | | | | | | |
| Analysis of Coal-Bearing Strata Near Cadomin | - | 507 | 15 762 | 3 731 | - | - | - | - | - | - | - | - | - | - | - | 20 000 |
| Reflective Seismic Investigation of Western Canadian Coalfields | - | - | - | - | 35 668 | 17 760 | - | - | - | - | - | - | - | - | - | 53 428 |
| Support Design for Underground Cavities in Weak Rock | - | - | - | 28 221 | 54 532 | 48 051 | - | - | - | - | - | - | - | - | - | 130 804 |
| Coal Ash Monitoring System | - | 13 555 | 24 185 | 25 130 | 8 763 | - | - | - | - | - | - | - | - | - | - | 71 633 |
| Automedium Cyclones | - | - | - | - | 22 929 | 34 842 | 37 940 | - | - | - | - | - | - | - | - | 95 711 |
| Beneficiation of Coal by Agglomeration in Pipelines | - | - | - | 49 944 | 60 947 | 74 523 | - | - | - | - | - | - | - | - | - | 185 414 |
| Hydroprocessing of Coal-Based Liquids | - | - | - | - | - | 45 593 | 34 463 | 4 880 | - | - | - | - | - | - | - | 84 936 |
| Supercritical Gas Extraction of Coal | - | - | - | - | - | 30 611 | 31 208 | 5 473 | - | - | - | - | - | - | - | 67 292 |
| Coal Conversion Waste-Water Treatment | - | - | - | - | - | 30 000 | 57 890 | - | - | - | - | - | - | - | - | 87 890 |
| Production of Activated Carbon | - | - | - | 32 364 | 7 077 | - | - | | - | - | - | | - | - | - | 39 441 |
| **SUBTOTAL: A/CERRF-Alberta Universities Program** | **0** | **14 062** | **39 947** | **139 390** | **189 916** | **291 380** | **161 501** | **10 353** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **836 549** |

| PROJECT TITLE | 1977/78 | 1978/79 | 1979/80 | 1980/81 | 1981/82 | 1982/83 | 1983/84 | 1984/85 | 1985/86 | 1986/87 | 1987/88 | 1988/89 | 1989/90 | 1990/91 | 1991/91 (Projected) | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Department-Funded Projects** | | | | | | | | | | | | | | | | |
| Smoky DENSECOAL Combustion Tests | - | - | - | - | - | - | - | - | 9 560 | - | - | - | - | - | - | 9 560 |
| Synthetic Fuels Program | - | - | - | - | - | - | - | 48 220 | - | - | - | - | - | - | - | 48 220 |
| Economic Evaluation of Coal/Oil Co-processing | - | - | - | - | - | - | - | 43 943 | 4 174 | - | - | - | - | - | - | 48 117 |
| Economics of Coal Gasification | - | - | - | - | - | - | - | - | - | - | 10 045 | - | - | - | - | 10 045 |
| Corrosion in Gasification Systems | - | - | - | - | - | - | - | - | - | | 43 069 | | - | - | - | 43 069 |
| Coal/Oil/Natural Gas Transportation System | - | - | - | - | - | - | - | - | - | - | 25 000 | - | - | - | - | 25 000 |
| Coal for Use in Enhanced Oil Recovery : Emission Control Technology | - | - | - | - | - | - | - | - | - | - | - | 14 625 | - | - | - | 14 625 |
| Alberta Coal Geology Project | - | - | - | - | - | - | - | - | - | 138 110 | 562 129 | 499 761 | 410 071 | 37 411 | - | 1 647 482 |
| **SUBTOTAL: Department-Funded Projects** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **92 163** | **13 734** | **138 110** | **640 243** | **514 386** | **410 071** | **37 411** | **0** | **1 846 118** |
| **TOTAL Alberta Coal Research** | **56 582** | **264 972** | **585 521** | **2 147 941** | **4 163 644** | **5 882 978** | **4 798 491** | **4 349 285** | **2 882 298** | **5 535 681** | **4 574 296** | **4 188 682** | **4 397 484** | **2 514 752** | **781 184** | **46 583 973** |
| **Western Canadian Low-Sulphur Coal to Ontario Program** | | | | | | | | | | | | | | | | |
| HYDROSIZER for Fine Coal Recovery from Tailings | - | - | - | - | - | - | - | - | - | - | - | 21 000 | - | - | - | 21 000 |
| Testing of ARCOFLUX 130 | - | - | - | - | - | - | - | - | - | - | - | 5 040 | - | - | - | 5 040 |
| Thick Seam Extraction and Continuous Haulage Mining Demonstration | - | - | - | - | - | - | - | - | - | - | - | 291 773 | 1 746 540 | 353 655 | 314 117 | 2 706 085 |
| Air-Sparged Hydrocyclone | - | - | - | - | - | - | - | - | - | - | - | 41 577 | 86 354 | - | - | 127 931 |
| On-Line Coal Analysers | - | - | - | - | - | - | - | - | - | - | - | - | 83 733 | - | - | 83 733 |
| Tailings Reclamation | - | - | - | - | - | - | - | - | - | - | - | 3 649 | 25 182 | 8 380 | 6 940 | 44 151 |
| transCOM Co-ordinated Vendor Test | - | - | - | - | - | - | - | - | - | - | - | - | 296 623 | 51 452 | - | 348 075 |
| Developing A Practical Model For The Compound Water Cyclone | - | - | - | - | - | - | - | - | - | - | - | - | - | 56 288 | - | 56 288 |
| Feasibility Study - IGCC Power Plant | - | - | - | - | - | - | - | - | - | - | - | - | - | 124 167 | - | 124 167 |
| Thermal Drying of Western Canadian Low-Rank Coals | - | - | - | - | - | - | - | - | - | - | - | - | - | 9 283 | - | 9 283 |
| **TOTAL: Western Canadian Low-Sulphur Coal to Ontario Program** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **363 039** | **2 238 432** | **603 225** | **321 057** | **3 525 753** |
| **ADMINISTRATION** | - | - | - | - | - | - | - | - | - | - | - | - | **50 000** | **185 488** | **184 263** | **369 371** |
| **TOTAL: COAL RESEARCH PROGRAMS** | **56 582** | **264 972** | **585 521** | **2 147 941** | **4 163 644** | **5 882 978** | **4 798 491** | **4 349 285** | **2 882 298** | **5 535 681** | **4 574 296** | **4 471 781** | **6 625 988** | **3 117 977** | **1 822 241*** | **50 118 826** |

* Additional funds from the Department of Energy will bring the total to $2 275 000

**Figure 1: Research Expenditure on Approved Projects (excluding Coal Research Centre, Devon).**

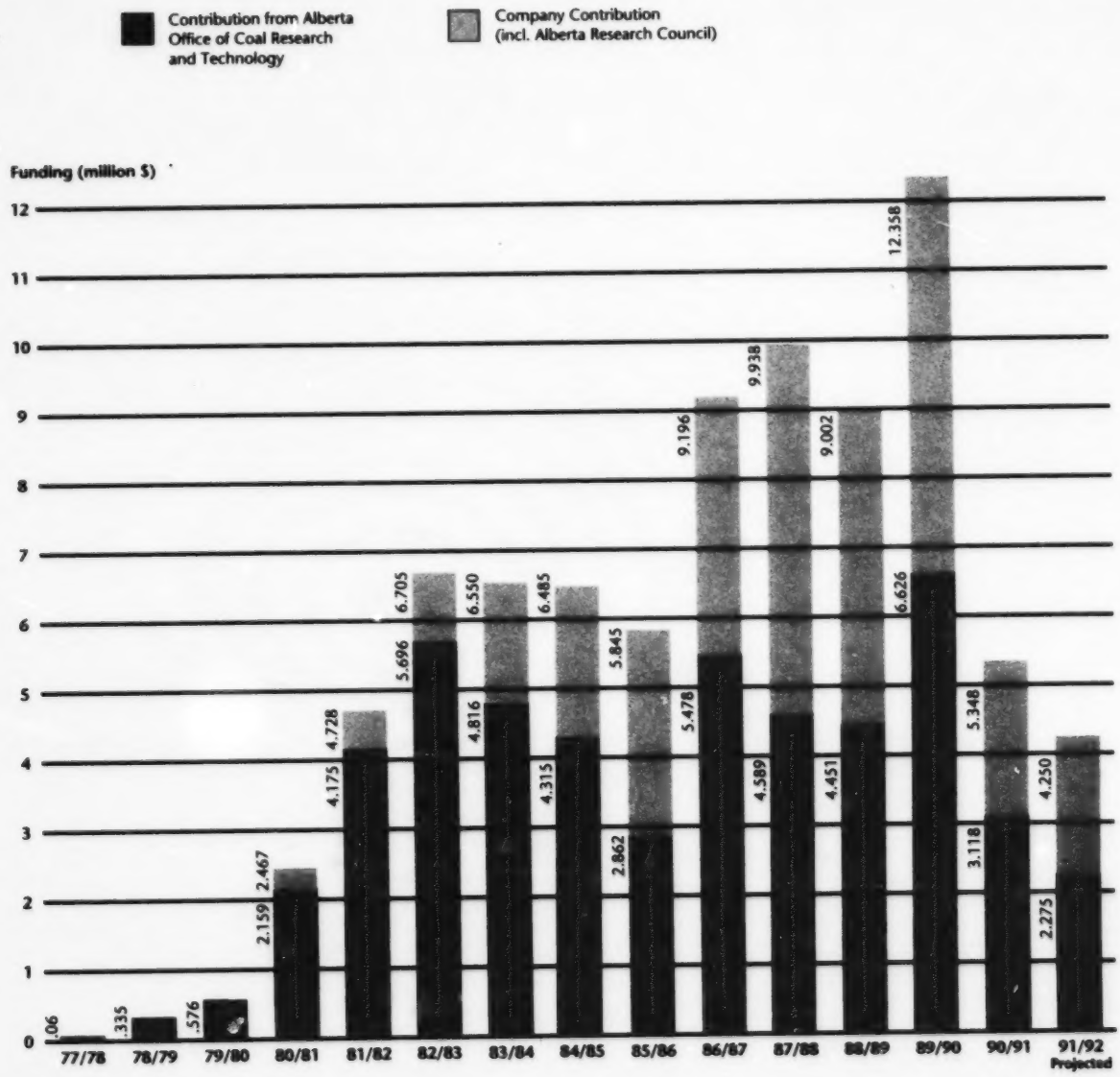
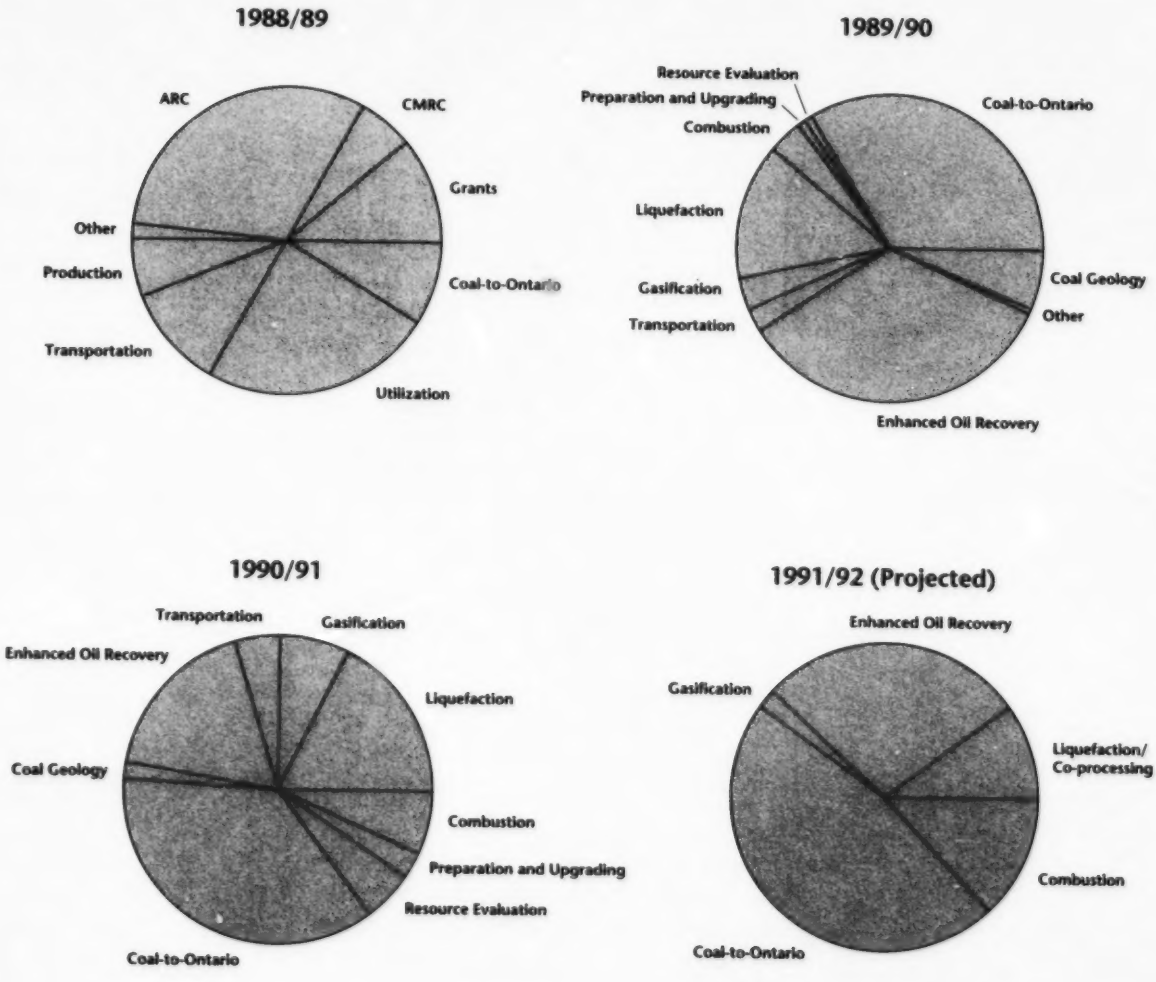


**Figure 2: Distribution of Alberta Office of Coal Research and Technology Funding Contributions**



# Appendix

Projects Supported by the Alberta Office of Coal Research and Technology and Their Status

## A/CERRF-Funded Projects

| *Project* | *Researcher* | *Status* |
|---|---|---|
| **Resource Evaluation** | | |
| Analysis of Coal-Bearing Strata Near Cadomin | H.A.K. Charlesworth, University of Alberta | Completed in 1981/82 |
| Creep Characteristics of Coal | D.M. Cruden, University of Alberta | Completed in 1984/85 |
| Reflective Seismic Investigation of Western Canadian Coalfields | D.C. Lawton, The University of Calgary | Completed in 1984/85 |
| VLF Geophysical Methods in Coal Exploration | Smoky River Coal Limited | Completed in 1985/86 |
| Geophysical Instrumentation | Coal Mining Research Company | Completed in 1985/86 |
| Geotechnical Properties of Overburden | Coal Mining Research Company | Completed in 1985/86 |
| Surface Geophysical Coal Exploration | TransAlta Utilities Corporation and Others | Completed in 1986/87 |
| 3-D Structural Geometry | D.A. Spratt, The University of Calgary | Completed in 1986/87 |
| In-Seam Coal Characterization | Coal Mining Research Company | Completed in 1987/88 |
| Seismic Modelling of Shallow Coalfields | D.C. Lawton, The University of Calgary | Completed in 1989/90 |
| Downhole Geophysical Characterization of Overburden | TransAlta Utilities Corporation and Others | Completed in 1990/91 |
| Surface Geophysical Techniques for Foothills and Mountain Coalfield Exploration | Esso Resources Canada Limited and Others | Completed in 1990/91 |
| Coal Bed Methane: An Alberta Opportunity | Alberta Research Council | Continuing |
| **Mining** | | |
| Support Design for Underground Cavities in Weak Rock | N.R. Morgenstern, University of Alberta | Completed in 1978/79 |
| Coal Mining Research | Coal Mining Research Company | Completed in 1985/86 |
| Coal Mining in 2035 | Coal Mining Research Company | Completed in 1985/86 |
| Triaxial Test Development | Coal Mining Research Company | Completed in 1986/87 |
| Ground Movements in Coal Mines | D.M. Cruden, University of Alberta | Completed in 1986/87 |

| *Project* | *Researcher* | *Status* |
|---|---|---|
| Mining 2035 Workshop | Coal Mining Research Company | Completed in 1986/87 |
| Robotics for Mine Control | Coal Mining Research Company | Completed in 1986/87 |
| Non-Cable Vehicle Guidance | Coal Mining Research Company | Completed in 1987/88 |
| Lasers in Coal Mining | Coal Mining Research Company | Completed in 1987/88 |
| Geostatistics | Coal Mining Research Company | Completed in 1987/88 |
| Footwall Anchoring | Smoky River Coal Limited | Completed in 1987/88 |
| Time-Dependent Behaviour of Coal Measure Rocks | R. Day, The University of Calgary | Completed in 1988/89 |
| Deformation and Progressive Failure of Open-Pit Highwalls | N.R. Morgenstern, University of Alberta | Completed in 1988/89 |
| Automated Machine Control for Optimized Mining (AMCOM) | Coal Mining Research Company | Completed in 1988/89 |
| Dragline Operations Monitor | Coal Mining Research Company | Completed in 1988/89 |
| **Preparation and Upgrading** | | |
| Coal Ash Monitoring System | L.R. Plitt, University of Alberta | Completed in 1982/83 |
| Automedium Cyclones | L.R. Plitt, University of Alberta | Completed in 1984/85 |
| Beneficiation of Coal by Agglomeration in Pipelines | Alberta Research Council/ University of Alberta | Completed in 1984/85 |
| Coal Preparation Research | Coal Mining Research Company | Completed in 1985/86 |
| Coal Comminution | Coal Mining Research Company | Completed in 1986/87 |
| Numerical Analysis of Process Yield Losses | Coal Mining Research Company | Completed in 1986/87 |
| Advanced Processes for Low-Rank Coal | Coal Mining Research Company | Completed in 1986/87 |
| Properties of Thermally Dried Coals | Coal Mining Research Company | Completed in 1986/87 |
| Stabilization of Dried Coal | Coal Mining Research Company | Completed in 1986/87 |
| Agglomeration of Low-Rank Alberta Thermal Coals | Alberta Research Council | Completed in 1986/87 |
| Agglomeration for Beneficiation | Manalta Coal Limited | Completed in 1986/87 |
| Preparation and Upgrading Assistance to AOCRT | Coal Mining Research Company | Completed in 1987/88 |
| Moisture and Ash On-Stream Analyser | Coal Mining Research Company | Completed in 1987/88 |
| Recovery of Coal from Tailings | Coal Mining Research Company | Completed in 1987/88 |

| *Project* | *Researcher* | *Status* |
|---|---|---|
| Fine Coal Technical Assistance | Coal Mining Research Company | Completed in 1987/88 |
| Froth Flotation Study at Coal Valley | Luscar Sterco (1977) Ltd. | Completed in 1987/88 |
| Washery Optimization | Coal Mining Research Company | Completed in 1988/89 |
| Coal Beneficiation Process | Gulf Canada Resources Limited and Unocal Canada Limited | Completed in 1988/89 |
| Agglomeration of Coking Coal | Smoky River Coal Limited | Completed in 1988/89 |
| WESTCOAL Separator Phase II | Coal Mining Research Company | Completed in 1989/90 |
| Coal Production Program Planning | Coal Mining Research Company | Completed in 1989/90 |
| Coal Agglomeration Process Development | Alberta Research Council | Completed in 1990/91 |
| Particle Distribution in Slurry Flow Through Tees and Manifolds | J.H. Masliyah, University of Alberta | Completed in 1990/91 |
| Electrocoagulation | Luscar Sterco (1977) Ltd. and Others | Continuing |
| Coal/Oil Upgrader | Fording Coal Limited and Others | Continuing |
| **Combustion** | | |
| Combustion of Agglomerated Coal | Luscar Ltd. | Completed in 1985/86 |
| Combustion Process Research | Alberta Research Council | Completed in 1986/87 |
| Combustion Characteristics of Alberta Coals | Alberta Research Council | Completed in 1986/87 |
| Combustibility of Agglomerates | Alberta Research Council | Completed in 1986/87 |
| Combustion Program Planning | Alberta Research Council | Completed in 1987/88 |
| Influence of Porosity on Combustion | Alberta Research Council | Completed in 1987/88 |
| Causes of Spontaneous Combustion of Western Canadian Coals | F.W. Bachelor, The University of Calgary | Completed in 1987/88 |
| Combustibility of Upgraded Alberta Coals | Alberta Research Council | Completed in 1987/88 |
| Evaluation of Blending on Combustibility | Alberta Research Council | Completed in 1987/88 |
| Prediction of Coal Combustibility | Esso Resources Canada Limited | Completed in 1987/88 |
| Combustion Properties of Alberta Coals and Chars | Alberta Research Council | Completed in 1988/89 |
| Spontaneous Combustion of Thermally Treated Coals | Unocal Canada Limited and Others | Completed in 1988/89 |

| *Project* | *Researcher* | *Status* |
|---|---|---|
| International Energy Agency Basic Coal Combustion Science | Netherlands Energy Research Foundation ECN | Completed in 1988/89 |
| A Thermodynamic Model for the Spontaneous Combustion of Coal | R. Paul, The University of Calgary | Completed in 1989/90 |
| Travel Grant to Study Sources of Ash in Controlled Conditions at IFRF, IJmuiden | R.C. Joshi, The University of Calgary | Completed in 1989/90 |
| Program Extension to IEA Annex II Basic Coal Combustion Science | Netherlands Energy Research Foundation ECN | Completed in 1990/91 |
| Coal Utilization Program Planning | Alberta Research Council | Continuing |
| Ash Properties of Alberta Coals | Alberta Research Council | Continuing |
| **Liquefaction/Co-processing** | | |
| Coal Liquefaction Study | Kilborn Alberta Limited | Completed in 1981/82 |
| Coal Liquefaction Feasibility Study | Contar Systems Engineering Ltd. and Others | Completed in 1984/85 |
| PYROSOL Process Review | Canadian Utilities Ltd. and Luscar Ltd. | Completed in 1985/86 |
| Liquefaction Process Improvement | Alberta Research Council | Completed in 1985/86 |
| Hydroprocessing of Coal-Based Liquids | I.G. Dalla Lana, University of Alberta | Completed in 1985/86 |
| Supercritical Gas Extraction of Coal | N. Berkowitz, University of Alberta | Completed in 1985/86 |
| ENR/ARC Coal Conversion Research | Alberta Research Council | Completed in 1986/87 |
| New Liquefaction Processes | Alberta Research Council | Completed in 1986/87 |
| Preliminary Economic Evaluation of a Multistage Coal/Heavy Oil Co-processing Concept and Development of a Simple Process Evaluation | Alberta Research Council | Completed in 1986/87 |
| Isotopic Analysis of Co-processing Schemes | K. Muehlenbachs, University of Alberta | Completed in 1986/87 |
| Secondary Upgrading | Alberta Research Council | Completed in 1987/88 |
| Functional Group Analysis of Coal Liquids | M.R. Gray, University of Alberta | Completed in 1987/88 |
| Chemistry of Coal Liquefaction | Alberta Research Council | Completed in 1988/89 |
| Secondary Upgrading of Co-processing Products | Alberta Research Council | Completed in 1988/89 |

| *Project* | *Researcher* | *Status* |
|---|---|---|
| Supercritical Gas Extraction of Coal | N. Berkowitz, University of Alberta | Completed in 1988/89 |
| Liquefaction of Coal with Natural Gas | M.R. Gray, University of Alberta | Completed in 1988/89 |
| Hydroprocessing of Coal-Derived Liquids | I.G. Dalla Lana, University of Alberta | Completed in 1988/89 |
| Isotopic Studies of Coal/Bitumen Co-processing Schemes | K. Muehlenbachs, University of Alberta | Completed in 1989/90 |
| Molecular Interactions Between Heavy Oil and Coal Species During Co-processing | P.D. Clark, The University of Calgary | Completed in 1989/90 |
| Product and Process Characterization | Alberta Research Council | Completed in 1990/91 |
| Co-processing Process Development | Canadian Energy Developments Inc. | Completed in 1990/91 |
| Co-processing of Coal with Molten Halide Catalysts | A. Chakma, The University of Calgary | Completed in 1990/91 |
| Combined Processing of Coal, Heavy Oil and Natural Gas | M.R. Gray, University of Alberta | Continuing |
| Specialty Chemicals from Coal-Derived Liquids | Alberta Research Council | Continuing |
| Coal/Oil Co-processing Using a Counterflow Reactor | Canadian Energy Developments, Inc. | Continuing |
| Co-processing of Coal and Heavy Oil in Alberta, Phase II | AOSTRA | Continuing |
| **Gasification** | | |
| Gasification of Western Canadian Coals | TransAlta Utilities Corporation and Others | Completed in 1986/87 |
| Fluidized Bed Gasification of Highvale Coal | TransAlta Utilities Corporation and Others | Completed in 1987/88 |
| Gasification Process Research | Alberta Research Council | Completed in 1987/88 |
| Gasification Properties of Alberta Coals | Alberta Research Council | Completed in 1987/88 |
| Gasification Laboratory Facilities | Alberta Research Council | Completed in 1987/88 |
| Gasification Characteristics of Alberta Coals | Alberta Research Council | Completed in 1988/89 |
| Devolatilization Properties of Alberta Coals | Alberta Research Council | Completed in 1988/89 |

| *Project* | *Researcher* | *Status* |
|---|---|---|
| IGCC Utility Applications | TransAlta Utilities Corporation and Others | Completed in 1989/90 |
| Gasification Properties of Alberta Coals | Alberta Research Council | Continuing |
| **Transportation** | | |
| Coal Slurry Pipeline Research | Pembina Resources Ltd. | Completed in 1984/85 |
| Coal Market Access Model | Trimac Consulting Services Ltd. | Completed in 1988/89 |
| Coal-Oil Slurry Pipelining | Unocal Canada Limited | Completed in 1988/89 |
| Coal Slurry Technology | Salzgitter Industriebau GmbH and Others | Completed in 1990/91 |
| **Environment** | | |
| Coal Conversion Waste-Water Treatment | S.E. Hrudey, University of Alberta | Completed in 1984/85 |
| Low $NO_x/SO_x$ Burner | TransAlta Utilities Corporation | Completed in 1986/87 |
| Coal Conversion Waste-Water Treatment | S.E. Hrudey, University of Alberta | Completed in 1987/88 |
| Sorbent Injection Study | Alberta Power Limited | Completed in 1988/89 |
| A State-of-the-Art Review on $CO_2$ Separation/Disposal Technologies | TransAlta Utilities Corporation and Others | Completed in 1990/91 |
| **Markets** | | |
| Conversion from Oil to Coal-Water Fuels | Smoky River Coal Limited | Completed in 1985/86 |
| Production of Activated Carbon | E.L. Tollefson, The University of Calgary | Completed in 1985/86 |
| Activated Carbon From Coal | E.L. Tollefson, The University of Calgary | Completed in 1987/88 |
| **Enhanced Oil Recovery** | | |
| Fuel Options for Enhanced Oil Recovery | L.A. Smith Consulting and Development Ltd. | Completed in 1985/86 |
| Coal Use in Enhanced Oil Recovery | Luscar Ltd. and Others | Completed in 1987/88 |
| Coal-Fired Steam Injection Boiler | Fording Coal Limited and Others | Completed in 1988/89 |
| Application of the LNS Burner to an Oil Field Steam Generator | TransAlta Resources Investment Corporation and Others | Completed in 1988/89 |

| *Project* | *Researcher* | *Status* |
|---|---|---|
| Economics of Coal Use for Heavy Oil Recovery | Shell Canada Limited | Completed in 1989/90 |
| Coal/Condensate Slurry Pipelining | Unocal Canada Limited | Completed in 1990/91 |
| Coal/Condensate Slurry Pipelining - Engineering/Cost Study | Unocal Canada Limited | Completed in 1990/91 |
| LNS Burner Steam Generator Demonstration | TransAlta Resources Investment Corporation and Esso Resources Canada Limited | Continuing |
| **Other** | | |
| Coal Technology Information Centre | Alberta Research Council | Completed in 1985/86 |
| CTIC Review | Crozier Information Resources Consulting Ltd. | Completed in 1985/86 |
| Data Gathering for Research Planning | Coal Mining Research Company | Completed in 1986/87 |
| Electrolysis of Coal Slurries | V.I. Birss, The University of Calgary | Completed in 1986/87 |
| Sulphur Isotope Studies of Coal | R.H. Krouse, The University of Calgary | Completed in 1988/89 |
| Electrolysis of Coal Slurries II | V.I. Birss, The University of Calgary | Completed in 1988/89 |
| Distributed Chemical and Physical Properties of Coal | P.J. Crickmore, University of Alberta | Completed in 1988/89 |
| Magnetic and Electric Properties of Alberta Coals | H.A. Buckmaster, The University of Calgary | Completed in 1989/90 |
| Distribution of Oxygen Forms in Western Canadian Low-Rank Coals | N. Berkowitz, University of Alberta | Completed in 1989/90 |

| *Project* | *Researcher* | *Status* |
|---|---|---|

## Department-Funded Projects

| | | |
|---|---|---|
| Synthetic Fuels Program | SRI International | Completed in 1984/85 |
| Economic Evaluation of Coal/Oil Co-processing | HRI Inc. | Completed in 1984/85 |
| Smoky DENSECOAL Combustion Tests | Monenco Consultants Ltd. | Completed in 1985/86 |
| Economics of Coal Gasification | Alberta Power Limited and Others | Completed in 1987/88 |
| Corrosion in Gasification Systems | W.J.D. Shaw, The University of Calgary | Completed in 1987/88 |
| Coal/Oil/Natural Gas Transportation System | CERI Energy Research Ltd. | Completed in 1987/88 |
| Coal for Use in Enhanced Oil Recovery: Emission Control Technology | Esso Resources Canada Limited and Others | Completed in 1987/88 |
| Alberta Coal Geology Project | Alberta Research Council | Completed in 1989/90 |

## Western Canadian Low-Sulphur Coal to Ontario Program

| | | |
|---|---|---|
| HYDROSIZER for Fine Coal Recovery from Tailings | Obed Mountain Coal Company Limited | Completed in 1989/90 |
| Testing of ARCOFLUX 130 | Obed Mountain Coal Company Limited | Completed in 1989/90 |
| transCOM Co-ordinated Vendor Tests | Unocal Canada Limited | Completed in 1989/90 |
| Thermal Drying of Western Canadian Low-Rank Coals | TransAlta Utilities Corporation | Completed in 1990/91 |
| Developing a Practical Model for the Compound Water Cyclone | Cyclone Engineering Sales Ltd. | Terminated in 1990/91 |
| On-Line Coal Analysers | RadioMetries Engineering Ltd. | Terminated in 1990/91 |
| Feasibility Study – IGCC Power Plant | The Coal Association of Canada | Continuing |
| Thick-Seam Extraction and Continuous Haulage Mining Demonstration | Smoky River Holdings Ltd. | Continuing |
| Air-Sparged Hydrocyclone | Hydro Processing & Mining Ltd. | Continuing |
| Tailings Reclamation | Luscar Sterco (1977) Ltd. | Continuing |

**Publications currently available are:**

Alberta Coal: Energy for the World. 27 pages, August 1987.

Annual Review 1984/85, Alberta Office of Coal Research and Technology. 24 pages, 1985.

Annual Review 1985/86, Alberta Office of Coal Research and Technology. 26 pages, 1986.

Annual Review 1986/87, Alberta Office of Coal Research and Technology. 32 pages, 1988.

Annual Review 1987/88, Alberta Office of Coal Research and Technology. 62 pages, 1989.

Annual Review 1988/89, Alberta Office of Coal Research and Technology. 60 pages, 1990.

Annual Review 1989/90, Alberta Office of Coal Research and Technology. 62 pages, 1991.

Annual Review 1990/91, Alberta Office of Coal Research and Technology. 55 pages, 1992.

An Economic Analysis of Coal Pipeline Systems. 6 pages, January 1987.

Opportunities to Use Coal in Enhanced Oil Recovery. 8 pages, May 1988.

Development of an Agglomeration Process to Beneficiate and Transport Alberta Coals. 14 pages, June 1988.

Gasification of Western Canadian Coals. 14 pages, June 1988.

Coal Research Centre, Devon. 10 pages, August 1988.

Co-processing Studies of Alberta Subbituminous Coals. 14 pages, December 1988.

Mathematical Modelling of Automedium Cyclones. 10 pages, January 1989.

The Technical Committee Approach to Coal Research. 6 pages, January 1989.

Advanced Coal Mining Techniques for Alberta. 10 pages, March 1989.

Some Combustion Studies of Alberta Coals. 13 pages, May 1989.

Gasification of Alberta Coals. 10 pages, June 1989.

Development of Clean Coal Technologies for Alberta. 12 pages, July 1989.

Coal Preparation Research in Alberta. 22 pages, September 1989,

Development of a Coal-Fired Boiler for Steam Injection in Heavy Oil Recovery. 8 pages, November 1989.

Studies of Fine Coal Cleaning and Upgrading Processes for Alberta Coals. 10 pages, November 1989.

Methods for Producing Liquid Hydrocarbons from Coal. 17 pages, March 1990.

Geotechnical Studies of Overburden and Coal at Alberta Coal Mines. 14 pages, October 1990.

**Persons wishing to receive future Office publications, or who require more information about Office projects and programs, should contact:**

Chairman
Alberta Office of Coal Research and Technology
Alberta Energy
11th Floor, North Petroleum Plaza
9945 - 108 Street
Edmonton, Alberta
T5K 3G6
Telephone: (403) 427-8042
Telex: 037-3676
Fax: (403) 422-0975

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Edmonton, Alberta
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Main Floor, Bantrel Building
703 - 6th Avenue S.W.
Calgary, Alberta
T2P 0T9
Telephone: (403) 297-6324

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